МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

КАФЕДРА КОНСТРУКЦІЇ ЛІТАЛЬНИХ АПАРАТІВ

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Завідувач кафедри
д.т.н., професор
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КВАЛІФІКАЦІЙНА РОБОТА
ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА
ЗІ СПЕЦІАЛЬНОСТІ
«АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА»

Тема: «Розробка нового дизайну інтер'єру пасажирської кабіни літака з панорамним видом»

Виконавець: _________ **Ліана ПОГНІРИБКО**

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Київ 2022

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

PERMISSION TO DEFEND
Head of the department,
Dr. of Sc., professor
_________ Sergiy IGNATOVYCH
"___" _________________ 2022

MASTER DEGREE THESIS
ON SPECIALITY
"AVIATION AND ROCKET-SPACE TECHNOLOGIES"

Topic: "Development of a new aircraft interior passenger cabin design with panoramic view"

Fulfilled by: ____________ **Liana POHNIRYBKO**

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

Labor protection advisor:
PhD, associate professor ____________ **Katerina KAZHAN**

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Kyiv 2022

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет аерокосмічний

Кафедра конструкції літальних апаратів

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ЗАТВЕРДЖУЮ
Завідувач кафедри
д.т.н., професор
__________Сергій ІГНАТОВИЧ
«___» _____________2022 р.

ЗАВДАННЯ

на виконання кваліфікаційної роботи пошукача

Ліана ПОГНІРИБКО

1. Тема роботи «Розробка нового дизайну інтер'єру пасажирської кабіни літака з панорамним видом», затверджена наказом ректора від 05 жовтня 2022 року №1861/ст.

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

3. Вихідні дані до роботи: крейсерська швидкість V_{cr} = 905 км/год, дальність польоту L = 9700 км, крейсерська висота польоту H_{op} = 13 km.

4. Зміст пояснювальної записки: вступ, основна частина, що включає аналіз літаків-прототипів і короткий опис проектованого літака, обґрунтування вихідних даних для розрахунку, розрахунок основних льотно-технічних та геометричних параметрів літака, компонування пасажирської кабіни, розрахунок центрування літака, спеціальна частина, яка містить проект дизайну пасажирської кабіни літака, охорона праці та навколишнього середовища.

5. Перелік обов'язкового графічного (ілюстративного) матеріалу: презентація Power Point, малюнки та схеми.

6. Календарний план-графік:

№	Завдання	Термін виконання	Відмітка про виконання
1	Отримання завдання, обробка статистичних даних.	06.10.2022-18.10.2022	
2	Розрахунок мас літака та його основних льотно-технічних характеристик.	19.10.2022-29.10.2022	
3	Розрахунок центрування літака.	30.10.2022-07.11.2022	
4	Розробка креслень по основній частині.	06.10.2022-31.10.2022	
5	Розробка нового дизайну інтер'єру пасажирської кабіни літака з панорамним видом	01.11.2022-04.11.2022	
6	Оформлення кваліфікаційної роботи	05.11.2022-10.11.2022	

7. Консультанти з окремих розділів:

Розділ	Консультанти	Дата, підпис	
		Завдання видав	Завдання прийняв
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Охорона навколишнього середовища	к.т.н., професор Леся ПАВЛЮХ		

8. Дата видачі завдання: 5 жовтня 2022 р.

Керівник кваліфікаційної роботи _______ Володимир КРАСНОПОЛЬСЬКИЙ

Завдання прийняв до виконання _________ Ліана ПОГНІРИБКО

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty
Department of Aircraft Design

Educational Degree "Master"

Specialty 134 "Aviation and Rocket-Space Technologies"

Educational Professional Program "Aircraft Equipment"

APPROVED BY

Head of Department,

Dr. of Sc., professor

________ Sergiy IGNATOVYCH

"___" __________________ 2022

TASK

for the master degree thesis

Liana POHNIRYBKO

1. Topic: "Development of a new aircraft interior passenger cabin design with panoramic view", approved by the Rector's order № 1861/ст from 05 October 2022 year.

2. Period of work execution: from 05 October 2022 year to 30 November 2022 year.

3. Initial data: cruise speed V_{cr} = 905 km/h, flight range L = 9700 km, operating altitude H_{op} = 13 km.

4. Content: introduction; main part: analysis of prototypes and brief description of designing aircraft, selection of initial data, wing geometry calculation and aircraft layout, landing gear design, engine selection, center of gravity calculation, special part: introduction and calculation of the new fuselage concept, labor and environmental protection.

5. Required material: Power Point Presentation, drawings and diagrams.

6. Thesis schedule:

№	Task	Time limits	Done
1	Task receiving, processing of statistical data.	06.10.2022-18.10.2022	
2	Aircraft take-off mass determination and flight performances calculation.	19.10.2022-29.10.2022	
3	Aircraft centering determination.	30.10.2022-07.11.2022	
4	Graphical design of the aircraft and its layout.	06.10.2022-31.10.2022	
5	Development of a new aircraft interior passenger cabin design with panoramic view	01.11.2022-04.11.2022	
6	Edit aand correct the draft, modify the format.	05.11.2022-10.11.2022	

7. Special chapter advisers:

Chapter	Adviser	Date, signature	
		Task issued	Task received
Labor protection	PhD, associate professor Katerina KAZHAN		
Environmental protection	PhD, professor Lesya PAVLYUKH		

8. Date of issue of the task: 8 September 2022 year.

Supervisor: ____________ Volodymyr KRASNOPOLSKYI
Student: _____________ Liana POHNIRYBKO

РЕФЕРАТ

Пояснювальна записка дипломної роботи магістра "Розробка нового дизайну інтер'єру пасажирської кабіни літака з панорамним видом"

91 с., 29 рис., 9 табл., 17 джерел

Ця дипломна робота присвячена розробці нового дизайну інтер'єру пасажирської кабіни літака з панорамним видом, що збільшить міцність фюзеляжу.

В роботі використовуються метод порівняльного аналізу літаків-прототипів для вибору найбільш обґрунтованих технічних рішень, а також методи інженерних розрахунків для отримання основних параметрів проектованого літака. Застосовано аналіз напружено-деформованого стану для розрахунку на міцність фюзеляжу.

Практична значення роботи полягає в тому, що в спеціальній частині обґрунтовано застосування дизайну інтер'єру пасажирської кабіни літака з панорамним видом, що збільшує міцність фюзеляжу.

Матеріали роботи можуть бути використані в авіаційній галузі та в навчальному процесі авіаційних спеціальностей.

Пасажирський літак, аванпроект літака, центрування літака, компонування пасажирської кабіни, розрахунок на міцність нового дизайну фюзеляжу

ABSTRACT

Master degree thesis “Development of a new aircraft interior passenger cabin design with panoramic view”

91 pages, 29 figures, 9 table, 17 references

This thesis is devoted to the development of a new design of the passenger cabin with a panoramic view, which will increase the strength of the fuselage.

The work uses the method of comparative analysis of prototype aircraft to select the most reasonable technical solutions, as well as methods of engineering calculations to obtain the main parameters of the designed aircraft. The analysis of the stress-strain state was applied to calculate the strength of the fuselage.

The practical significance of the work is that the special part substantiates the application of the interior design of the passenger cabin of the aircraft with a panoramic view, which increases the strength of the fuselage.

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

Passenger aircraft, preliminary design, center of gravity calculation, passenger cabin layout, calculation of the fuselage strength

CONTENT

INTRODUCTION

The indisputable fact that science is inexorably moving forward makes us think about improving and simplifying our lives. Flights by air despite the fact that it is the safest kind of transport still make passengers worry about problems during flight. The main factors that negatively affect the popularity of aircraft travel are:

1. High price of tickets. Many passengers prefer to use trains that cost several times less.

2. The risk of an accident is rather high due to the fact that even an insignificant fail may cause a serious problem.

3. Although the seats are of a fairly high quality, it can be quite uncomfortable for people to be in the same position during several hours.

But it is possible to reduce the negative impact of these factors. If we bring modern technologies in an aircraft industry and use the perspective inventions, we can bring the popularity of air travel to new heights. For example, the new interior can be designed with the use of flexible screens. It can potentially increase the interior space, which will allow to install the seats with a lot of adjustments, so the passengers will feel much more comfortable. Also it will increase the reliability of an aircraft, because now it is possible to remove the stress concentrators - airplane windows. And, finally, the aircraft will become lighter, which means that the fuel consumption will be lower. This, in turn, will lower the ticket prices.

Therefore, the goal of this diploma project is the development of a new aircraft interior passenger cabin design with panoramic view.

1. PROJECT PART. PRELIMINARY DESIGN OF LONG-RANGE AIRCRAFT

1.1 Analysis of prototypes

1.1.1 Overview of general performances

To create an aircraft that meets safety requirements it is necessary to select the optimal design parameters such as: flight, technical, weight, geometric, aerodynamic and economic characteristics. In order to make the "General view of the plane" in the first stage are used statistic methods, approximate aerodynamic and statistical dependences. The second stage uses a full aerodynamic calculation, aircraft specified formulas of units weight calculations and experimental data.

For designed airplane were chosen the prototypes: McDonnell Douglas DC-10-10, Lockheed L-1011-1 TriStar, Boeing 767-100. Their statistic data are presented in table 1.1.

Table 1.1

Performances of prototypes

PARAMETER	AIRCRAFTS		
	DC-10-10	L-1011-1	Boeing 767-100
1	2	3	4
The purpose of airplane	Passenger	Passenger	Passenger
Crew/flight attend. persons	¾	¾	2/2
Maximum take-off weight, m_{tow}, kg	195 045 kg	200 000 kg	142 900 kg
Max pay-load, mk_{max}, kg	43 014 kg	41 370 kg	33 300 kg
Passengers	270	256	245
The flight altitude, $V_{w.ex}$, m	12 800 m	12 800 m	13 100 m
Flight range, $m_{k.max}$, km	6 500 km	4 963 km	7 200 km
Take-off distance $L_{TO.d.}$, m	2 700 m	3 300	1 900 m
Number and type of engines	3× GE CF6-6D	3×R-RRB211-2B	2×JT9D / PW4000 / CF6

Ending of the table 1.1

1	2	3	4
The shape of the fuselage cross-section	circular	circular	circular
Length of the fuselage	51.97 m	54.2 m	61.64 m
Length of the nose and rear part	15.59 m	16.26 m	18.49 m
Sweepback angle at 1/4 chord line, ^{0}	35	35	32

The scheme is determined by the relative position of the aircraft units, their number and shape. Aerodynamic and operational characteristics of the aircraft depend on the aircraft layout and aerodynamic scheme of the aircraft. Fortunately chosen scheme allows to increase safety, regularity of flights and economic efficiency of the aircraft.

1.1.2 Brief description of the main parts of the aircraft

The plane is a cantilever low-wing monoplane with bypass turbojet engines mounted in a wing and tricycle landing gear with a nose single-strut landing gear and two main gears.

A swept wing with a high aspect ratio is based on new supercritical airfoil. Fuselage has circular cross section. Empennage has a conventional configuration with adjustable vertical stabilizer mounted on the fin. Rudder and elevators are equipped with aerodynamic balance.

1.1.2.1 Fuselage

An important advantage comparatively to other modern airliners is the usage of a variety of lightweight but extremely strong alloys and composite materials in its design. Passenger cabin floor beams, aerodynamic fairings and other parts are made of composite materials. The total part of composite materials in design airplane is 9% of aircraft take-off weight. Thus, the weight of the aircraft and the cost of its production are significantly reduced [1].

The main part of the fuselage has a circular cross-section and at the rear goes into a blade-like tail cone in which the auxiliary power unit is located.

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

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

There are places for rest of the crew. They are located above the main cockpit and are equipped with ladders. The seating area consists of two chairs and two beds at the front of the fuselage as well as several seats at the rear of the fuselage. The aircraft is a long-haul liner able to perform non-stop commercial flights up to 18 hours in duration. However, the rules of various aviation regulators, professional and trade union organizations limit the hours of continuous work of the crew and flight attendants. For the rest of the pilots seats are usually reserved in business class or special containers are installed in the luggage compartment. They are equipped with berths and communication with the cockpit and the cabin of the aircraft. There is a resting compartment for the pilots in the front part of the aircraft above the passenger cabin. It includes two comfortable armchairs, 2 or 3 beds separated by partitions, a wardrobe, a TV set and a washbasin. The entrance to this compartment is via the stairs located at front left door. This solution allows to free up to 47 seats. The entrance to the flight attendant rest room is via a staircase in the central part of the aircraft. This compartment is designed for 6 or 7 flight attendants and equipped with berths, lighting and communication with the cabin.

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

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

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

The free economy class service provides online check-in for a flight, a separate check-in desk at the airport, an increased baggage allowance and hand luggage[1].

1.1.2.2 Wing

Wing has a supercritical airfoil optimized for a cruise speed 0.85M. The wings are designed with increased thickness and a longer span than previous airliners, resulting in greater payload and range, improved take-off performance and a higher cruising altitude.

The structural scheme of the wing is torsion-box type and includes two spars and set of stringers covered by working skin. The wing also serves as fuel tank and is able to carry up to 47,890 US gallons (181,300 L) of fuel. This capacity allows the aircraft to operate ultra-long-distance, trans-polar routes such as Toronto - Hong Kong. Wing is made of composite materials with a wider span. Its design features are based on the 767's wings. Under the fuselage in the wing fairing is located an emergency aircraft turbine – a small propeller that extends in emergency situations to provide a minimum power supply.

Airplane has folding wingtips of 11 feet (3.35 m) in length that will allow aircraft to use the same airport gates and taxiways as earlier airplanes[2].

1.1.2.3 Tail unit

The empennage consists of the horizontal and vertical stabilizers, elevators, and rudder. Each stabilizer is configured as a two-cell box, consisting of a main structural box and an auxiliary or forward torsion box, leading edges, tip, and fixed trailing edges. The main torsion boxes are made from CFRP composite material: solid-laminate front and rear spars, honeycomb sandwich ribs and integrally stiffened laminate skin panels.

The main box panels and spars feature a toughened-matrix It provides improved resistance to impact damage over previous brittle materials. The auxiliary torsion box and fixed trailing edges are glass or glass/CFRP sandwich panels with aluminum ribs. The leading edge, tip, and auxiliary spar are made of aluminum alloy.

The elevator and rudder are also constructed from CFRP sandwich panels, ribs, and spars and are hinged from the stabilizer or fin fixed trailing edge. The rudder incorporates a lower tab of CFRP sandwich construction.

The sweep of the vertical and horizontal tail unit is greater than the sweep of the wing so that the aerodynamic characteristics of the tail unit with an increase in the Mach number do not deteriorate faster than the characteristics of the wing. The grater sweep of the fin is also suitable because at the same time the horizontal stabilizer efficiency is increased due to the increase of its moment arm[3].

1.1.2.4 Landing gear

The aircraft has the largest landing gear and the biggest tires ever used in a commercial jetliner. The six-wheel bogies are designed to spread the load of the aircraft over a wide area without requiring an additional centerline gear. This helps reduce weight and simplifies the aircraft's braking and hydraulic systems. Each tire of six-wheel main landing gear can carry load of 76,000 lb (34,430 kg), which is heavier than other wide-bodies such as the 747-400[4].

1.1.2.5 Choice and description of power plant

During the aerodynamic calculation performed according program developed at department of aircraft design the maximum required take-off thrust was obtained. It is 381.6 kN. With respect to this value for designed aircraft was chosen the engine Rolls-Royce Trent 800.

It is an axial flow, high bypass turbofan with three coaxial shafts. The fan is driven by a 5-stage axial LP turbine (3300 rpm), the 8-stage IP compressor (7000 rpm) and the 6-stage HP compressor (10611 rpm) are each powered by a single stage turbine. It has an annular combustor with 24 fuel nozzles and is controlled by an EEC. The engine has a 6.4:1 bypass ratio in cruise and an overall pressure ratio of 33.9 to 40.7:1 at sea level, for a 340.6-413.4 kN (76,580-92,940 lbf) take-off thrust. The 280 cm (110 in) fan has 26 diffusion bonded, wide chord titanium fan blades [6]. Characteristics of this engine and its competitors are represented in table 1.2.

Table 1.2

Characteristics of engines

Name	PW 4000	Trent 800	GE 90
Type	Two spool high bypass ratio Turbofan	Three-shaft high bypass turbofan engine	Dual rotor, axial flow, high bypass turbofan
Compressor	1 fan, 7 LP, 11 HP	Eight-stage IP axial compressor, six-stage HP axial compressor	1 fan, 3-stage LP, 10-stage HP
Weight	16,260 lb 7,375 kg	13,400 lb 6,078 kg	17,400 lb 7,893 kg
Thrust	91,790-99,040 lbf 408-441 kN	76,580-92,940 lbf 340.6-413.4 kN	81,070-97,300 lbf 360.6-432.8 kN
Length	190.4 in (484 cm)	179.8 in (456.8 cm)	286.9 in (729 cm)
Bypass ratio	6.4:1	6.4:1	9:1
Diameter	112 in (284 cm)	280 cm (110 in)	123 in (310 cm)
Overall pressure ratio	42.8:1	40.7:1	40:1

1.2 Geometry calculations for the main parts of the aircraft

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

Layout consists of geometry calculation of principle structural units as wing, fuselage, tail unit and landing gear. Besides all above mentioned this analytical part includes choice of interior scheme. Its estimation includes dimensional calculation based on aircraft capacity requirements. This layout was implemented in line with both modern standards and well-established calculation methods.

1.2.1 Wing geometry calculation

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

Full wing area with extensions is:

$$S_w = \frac{m_0 \cdot g}{P_0} = \frac{289310 \cdot 9.8}{4977} = 569.668\, m^2 ,$$

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

Relative wing extensions area is 0.1

Wing area is:

$$S_w = 569.668 \cdot 0.8 = 455.73\ m^2.$$

Wing span is:

$$l = \sqrt{S_w \cdot \lambda_w} = \sqrt{455.73 \cdot 8.7} = 62.97\, m ,$$

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

Root chord is:

$$b_0 = \frac{2\, S_w \cdot \eta_w}{(1+\eta_w) \cdot l_w} = \frac{2 \cdot 455.73 \cdot 3}{(1+3) \cdot 62.97} = 10.86 \text{ m} ,$$

where b_0 – root chord, m; η_w – wing taper ratio.

Tip chord is:

$$b_t = \frac{b_0}{\eta_w} = \frac{10.86}{3} = 3.62\ m\ ,$$

where b_t – tip chord, m.

Maximum wing thickness is determined in the forehead i-section and is equal to:

$$c_i = c_w \cdot\ b_t = 0.11\ \cdot 3.62 = 0.3982\ m\ ,$$

where c_i – wing thickness in i-section, m; c_w – related wing thickness.

On board chord for trapezoidal shaped wing is:

$$b_{ob} = b_0\ \cdot \left(1 - \frac{(\eta_w - 1)\cdot D_f}{\eta_w \cdot l_w}\right) = \ 10.86\ \cdot \left(1 - \frac{(3-1)\cdot 6.2}{3\ \cdot 62.97}\right) = 10.15\ m\ ,$$

where b_b – wing board chord, m; D_f – fuselage diameter, m.

Type of structural scheme of the wing determines quantity of spars and its position as well as places of wing joints. The designed aircraft has two spars.

For mean aerodynamic chord length calculation was used geometrical method (fig. 1.1).

Mean aerodynamic chord is equal to:

$$b_{MAC} = 7.84\ m\ .$$

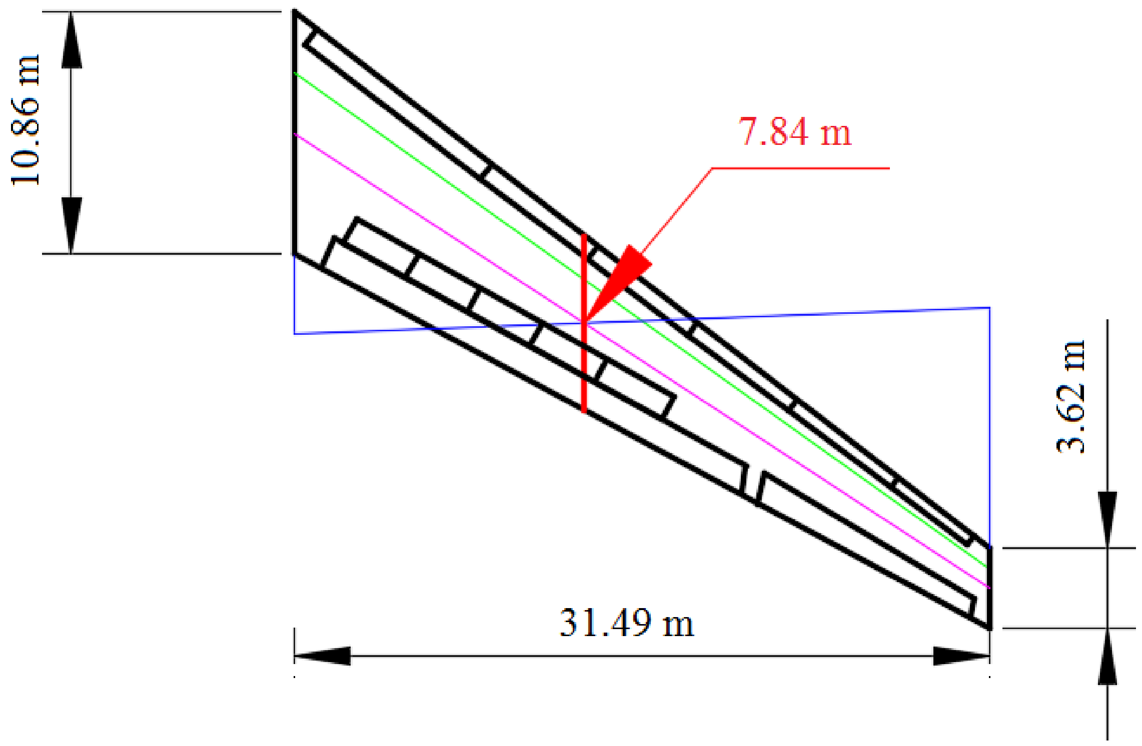


Fig. 1.1. Determination of mean aerodynamic chord.

After the determination of the geometrical characteristics of the wing it is possible to estimate ailerons and high-lift devices geometry.

Ailerons geometrical parameters are determined in next consequence:

Ailerons span is:

$$l_{ai} = 0.375 \cdot \frac{l_w}{2} = 0.375 \cdot \frac{62.97}{2} = 11.807\, m\,,$$

where l_{ail} – ailerons span, m.

Aileron area is:

$$S_{ai} = 0.065 \cdot \frac{S_w}{2} = 0.065 \cdot \frac{455.73}{2} = 14.81\, m^2\,,$$

where S_{ail} – ailerons area, m.

Increasing of l_{ail} and b_{ail} more than recommended values is not necessary and convenient. With the increase of l_{ail} more than given value the increase of the ailerons coefficient falls, and the high-lift devices span decreases. With b_{ail} increase, the width of the wing chord decreases.

In the airplanes of the third generation there is a tendency to decrease relative wing span and ailerons area. In this case for the transversal control of the airplane we use spoilers together with the ailerons. Due to this the span and the area of high-lift devices may be increased that improves take-off and landing characteristics of the aircraft.

The aim of determination of wing high-lift devices geometrical parameters is the providing take-off and landing coefficients of wing lift force, assumed in the previous calculations with the chosen rate of high-lift devices and the type of the airfoil.

Effectiveness of high-lift devices rises proportionally to the wing span increase, serviced by high-lift devices, so we need to obtain the biggest span of high lift devices due to use of flight spoiler and minimize the area of engine and landing gear nacelles.

To choose the structural scheme, hinge-fitting scheme and kinematics of the high-lift devices it is needed to take into account the statistics and experience of native and foreign aircraft designs. Have to be mentioned that in the majority of existing designs of high-lift devices they are made by spar structural scheme.

1.2.2 Fuselage layout

To choose the shape and the size of fuselage cross section it is needed to take into account aerodynamic demands. The shape of the fuselage influences on value of aerodynamic drag. Application of circular shape of fuselage nose part significantly minimize its drag. For transonic airplanes fuselage nose part has to be:

$$l_{nfp} = 2.1 \cdot D_f = 2.1 \cdot 6.2 = 13.02\ m,$$

where D_f – fuselage diameter, m; l_{fnp} – length of fuselage nose part.

Except aerodynamic requirements it is necessary to consider cross section shape, strength and layout requirements. To improve weight, strength and aerodynamic parameters circular cross section is usually chosen. In this case the fuselage has minimal skin area. As the partial case it may be used the combination of two or more vertical or horizontal series of circles.

The geometrical parameters are: fuselage diameter D_f; fuselage length l_f; fineness ratio λ_f; nose part fineness ratio λ_{np}. Fuselage length is determined considering the aircraft scheme, layout and airplane center-of-gravity position peculiarities and the landing angle of attack α_{land}.

Fuselage length is equal to:

$$l_f = \lambda_f \cdot D_f = 11.9 \cdot 6.2 = 69.44\, m\, .$$

Fuselage nose part fineness ratio is equal to:

$$\lambda_{fnp} = \frac{l_{fnp}}{D_f} = \frac{7.6}{6.2} = 1.23\, .$$

Length of the fuselage rear part is equal to:

$$l_{frp} = \lambda_{frp} \cdot D_f = 2.3 \cdot 6.2 = 14.26\, m\, .$$

During the determination of fuselage length it is needed to get minimum mid-section S_{ms} on the one hand and meet layout demands on the other hand.

For passenger and cargo airplanes fuselage mid-section first of all depends on the size of passenger or cargo cabin. One of the main parameter that determines the mid-section of passenger airplane is the height of the passenger cabin.

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

Cabin height is equal to:

$$H_{cab} = 0.296 + 0.383 B_{cabin} = 0.296 + 0.383 \cdot 5.720 = 2.487\, m\, ,$$

where H_{cab} – cabin height, m; B_{cab} – width of the cabin, m.

From the design point of view it is convenient to have round cross section, because in this case it’ll be the strongest and the lightest. But for passenger and cargo placing this shape is not always the most convenient one. In the most cases one of the most suitable ways is to use the combination of two circles intersection or oval shape of the fuselage. The oval shape is not suitable in the production because the upper and lower panels will bend due to extra pressure and will demand extra bilge beams and other structural features.

The windows are placed in one row. The shape of the window is rectangular with the rounded corners. The window step corresponds to bulkhead step and amount 500...510 mm.

In economic class with the scheme of seats location in one row (3 + 4 + 3) the appropriate width of the cabin is determined.

$$B_{cab} = 2 \cdot (n_{3block} \cdot b_{3block}) + n_{4block} \cdot b_{4block} + 2 \cdot b_{aisle} + 2\delta ,$$

where n_{3block} – number of three-seat blocks; b_{3block} – width of three-seat blocks, m; n_{4block} – number of four-seat blocks; b_{4block} – width of four-seat blocks, m; b_{aisle} – width of aisle, m; δ – distance between external armrests to the decorative panels, m.

$$B_{cab} = 2 \cdot 1430 + 1 \cdot 1940 + 2 \cdot 410 + 2 \cdot 50 = 5.720\, m .$$

The length of passenger cabin is equal to:

$$L_{cab} = L_1 + (n_{rows} - 1) \cdot L_{seatpitc\ h} + L_2 ,$$

where L_{cab} – length of passenger cabin, m; L_1 – distance from the wall to the back of the seat in first row, m; L_2 – distance from the back of the seat in last row to the wall, m; n_{rows} – number of rows; $L_{seatpitch}$ – seat pitch, m.

$$L_{cab} = 1200 + (44 - 1) \cdot 810 + 300 = 36.330\, m .$$

1.2.3 Luggage compartment

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

The area of cargo compartment is defined:

$$S_{cargo} = \frac{M_{bag}}{0.4K} + \frac{M_{cargo\ \&mail}}{0.6K} = \frac{20 \cdot 440}{0.4 \cdot 600} + \frac{15 \cdot 440}{0.6 \cdot 600} = 55\, m^2 ,$$

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

Cargo compartment volume is equal to:

$$V_{cargo} = \nu_c \cdot n_{pass} = 0.2 \cdot 440 = 88\ m^3$$

where V_{cargo} – cargo compartment volume, m^3; ν_c – cargo volume coefficient, m^3; n_{pass} – number of passengers. Luggage compartment design is similar to the prototype.

Luggage compartment design is similar to the prototype.

1.2.4 Galleys and buffets

Kitchen cupboards must be placed at the door, preferably between the cockpit and passenger cabin and have separate doors. Refreshment and food can not be placed near the toilet facilities or connect with wardrobe.

Volume of buffets (galleys) is equal to:

$$V_{galley} = \nu_g \cdot n_{pass} = 0.1 \cdot 440 = 44\ m^3,$$

where V_{galley} – galley volume, m^3; ν_g – galley volume coefficient, m^3; n_{pass} – number of passengers.

Area of buffets(galleys) is equal to:

$$S_{galley} = \frac{V_{galley}}{H_{cab}} = \frac{44}{2.487} = 17.69\ m^2,$$

where S_{galley} – galley area, m^2.

Number of meals per passenger breakfast, lunch and dinner – 0,8 kg; tea and water – 0,4 kg. One meal is 0,62 kg and passengers are fed every 3.5…4 hour of flight. Buffet design is similar to prototype.

1.2.5 Lavatories

Number of toilet facilities is determined by the number of passengers and flight duration: with t > 4 hours one toilet for 40 passengers.

$$n_{lav} = 11$$

Area of lavatory is:

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

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

1.2.6 Layout and calculation of tail unit basic parameters

One of the most important tasks of the aerodynamic layout is the choice of tail unit location. To provide longitudinal stability during overload its center of gravity should be placed in front of the aircraft focus and the distance between these points, related to the mean value of wing aerodynamic chord, determines the rate of longitudinal stability.

Determination of the tail unit geometrical parameters.

Area of vertical tail unit is equal to:

$$S_{VTU} = (0.12 \ldots 0.2) S_w = 0.12 \cdot 455.73 = 54.69\ m^2,$$

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

Area of horizontal tail unit is equal to:

$$S_{HTU} = (0.18 \ldots 0.25)\ Sw = 0.2 \cdot 455.73 = 91.15\ \text{m}^2,$$

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

Determination of the control surfaces area.

Elevator area is:

$$S_{el} = 0.3 \cdot 54.69 = 16.41\ \text{m}^2,$$

where S_{el} – elevator area, m^2; k_{el} – relative elevator area coefficient.

Rudder area is:

$$S_{rud} = 0.2 \cdot 91.15 = 18.23\ \text{m}^2,$$

where S_{rud} – rudder area, m^2; k_r – relative rudder area coefficient.

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

Elevator balance area is equal to:

$$S_{eb} = 0.2765 \cdot S_{HTU} = 0.2765 \cdot 91.15 = 25.2 \text{ m}^2 ,$$

where S_{eb} – area of elevator aerodynamic balance, m^2.

Rudder balance area is equal to:

$$S_{rb} = 0.2337 \cdot S_{VTU} = 12.78 \text{ m}^2 ,$$

where S_{rb} – area of rudder aerodynamic balance, m^2.

The area of elevator trim tab is:

$$S_{te} = 0.08 \cdot S_{el} = 0.08 \cdot 16.41 = 1.31 \text{ m}^2 ,$$

where S_{te} –elevator trim tab area, m^2.

Area of rudder trim tab is equal to:

$$S_{tr} = 0.06 \cdot S_{rud} = 0.06 \cdot 18.23 = 1.09 \text{ m}^2 ,$$

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

Root chord of horizontal stabilizer is:

$$b_{0HTU} = \frac{2S_{HTU} \cdot \eta_{HTU}}{(1+\eta_{HTU}) \cdot l_{HTU}} = \frac{2 \cdot 91.15 \cdot 2.5}{(1+2.5) \cdot 27.39} = 4.75\ m ,$$

where η_{HTU} – horizontal tail unit taper ratio; b_{0HTU} – root chord of horizontal stabilizer, m.

Tip chord of horizontal stabilizer is:

$$b_{tHTU} = \frac{b_{0HTU}}{\eta_{HTU}} = \frac{4.75}{2.5} = 1.9\ m ,$$

where b_{tHTU} – tip chord of horizontal stabilizer, m.

Root chord of vertical stabilizer is:

$$b_{0VTU} = \frac{2S_{VTU} \cdot \eta_{VTU}}{(1+\eta_{VTU}) \cdot l_{VTU}} = \frac{2 \cdot 54.69 \cdot 1.33}{(1+1.33) \cdot 27.39} = 2.28\,m\ ,$$

where b_{0VTU} – root chord of vertical stabilizer, m; η_{VTU} – vertical tail unit taper ratio; L_{VTU} – vertical tail unit span.

Tip chord of vertical stabilizer is:

$$b_{tVTU} = \frac{b_{0VTU}}{\eta_{VTU}} = \frac{2.28}{1.33} = 1.71\,m\ ,$$

where b_{tVTU} – tip chord of vertical stabilizer, m.

1.2.7 Landing gear design

In the primary stage of design when the airplane center-of-gravity position is defined and there is no drawing of airplane general view only the part of landing gear parameters may be determined.

Main wheel axis offset is:

$$e = 0.18 \cdot b_{MAC} = 0.18 \cdot 7.84 = 1.41\ \text{m}\ ,$$

where k_e – coefficient of axes offset; e – main wheel axes offset, m.

With the big wheel axial offset the lift-off of the front gear during take-off is complicated and with small, the ground strike of the airplane is possible when the loading of back of the aircraft comes first. Landing gear wheel base may be obtained from the expression:

$$B = k_b \cdot L_f = 0.4 \cdot 69.44 = 27.77\ \text{m}\ ,$$

where B – wheel base, m; k_b – wheel base calculation coefficient.

Front wheel axial offset will be equal to:

$$d_{ng} = B - e = 27.77 - 1.41 = 26.36\ \text{m}$$

where d_{ng} – nose wheel axes offset, m.

Wheel track is:

$$T = K \cdot B = 0.396 \cdot 27.77 = 11 \text{ m} ,$$

where T – wheel track, m; k_T – wheel track calculation coefficient.

To prevent nose-over the value K should be > 2H, where H – is the distance from runway to the center of gravity.

Nose wheel load is equal to:

$$F_n = \frac{g \cdot e \cdot k_d \cdot m_0}{B \cdot z} = \frac{9.81 \cdot 1.41 \cdot 1.5 \cdot 289\,310}{27.77 \cdot 2} = 108\,077.913\ N ,$$

where F_n – nose wheel load, N; k_d – dynamics coefficient; z – number of wheels.

Main wheel load is equal to:

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

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

$$F_m = \frac{9.81 \cdot (27.77 - 1.41) \cdot 1.5 \cdot 289\,310}{27.77 \cdot 2 \cdot 6} = 336\,753.403\ N .$$

According the calculated values of wheel loading and take-off speed it is possible choose the tires for landing gear from the catalog (table 1.3):

Table 1.3

Aviation tires for designing aircraft

Nose gear				Main gear			
Tire size	Ply Rating	Rated Speed (mph)	Rated load (Lbs)	Tire size	Ply Rating	Rated Speed (mph)	Rated load (Lbs)
38×12	20	210	25275	56×16	38	217	76000

1.3 Center of gravity calculation

1.3.1 Trim-sheet of the equipped wing

Mass of the equipped wing contains the mass of its structure, mass of the equipment placed in the wing and mass of the fuel. Regardless of the place of mounting (to the wing or to the fuselage) the main landing gear and the front gear are included in the mass register of the equipped wing. The mass register includes names of the objects, their masses and center of gravity coordinates. The origin of given coordinates of the mass centers is chosen by the projection of the leading edge of the mean aerodynamic chord (MAC) for the surface XOY. The positive values of the coordinates of the mass centers are accepted for the end part of the aircraft.

The list of the mass objects for the aircraft where the engines are located under the wing are given in the table 1.4. Coordinate of the center of mass for the equipped wing is defined by the formula (1.1).

$$X_w^{/} = \frac{\Sigma m_i^{/} x_i^{/}}{\Sigma m_i^{/}} \qquad (1.1)$$

where $X_w^{'}$ – center of mass for equipped wing, m; $m_i^{'}$ – mass of a unit, kg; x_i – center of mass of the unit, m.

Table 1.4

Trim sheet of equipped wing

N	Name	Mass		CG coordinates x_i (m)	Moment m_i x_i (kgm)
		Units	total mass m_i (kg)		
1	2	3	4	5	6
1	Wing (structure)	0,12764	36927,5284	3,528	130280,3202
2	Fuel system, 40%	0,0116	3355,996	3,528	11839,95389
3	Control system, 30%	0,0012	347,172	4,704	1633,097088
4	Electrical equip. 10%	0,00225	650,9475	0,784	510,34284
5	Anti-icing system 70%	0,00975	2820,7725	0,784	2211,48564
6	Hydraulic system, 70%	0,00889	2571,9659	2,166	5570,878139

Ending of the table 1.4

1	2	3	4	5	6
7	Power units	0,07032	20344,2792	-5.44	34585,27464
8	Equipped wing without fuel and LG	0,23165	67018,6615	0,617338485	41373,19894
9	Nose landing gear	0,003589	1038,33359	-23,066	23950,20259
10	Main landing gear	0,032301	9345,00231	4,704	43958,89087
11	Fuel	0,35246	101970,2026	3,528	359750,8748
	Equipped wing	0,62	179372,2	2,614859868	469033,1672

1.3.2 Trim-sheet of the equipped fuselage

Origin of the coordinates is chosen in the projection of the nose of the fuselage on the horizontal axis. The list of the mass objects for the equipped fuselage with engines mounted under the wing is given in table 1.5.

The CG coordinates of the equipped fuselage is determined by formula (1.2).

$$X_f = \frac{\Sigma m_i^/ X_i^/}{\Sigma m_i^/}; \qquad (1.2)$$

where $X_f^{'}$ – center of mass for equipped fuselage, m; $m_i^{'}$ – mass of a unit, kg; x_i – center of mass of the unit, m.

After the determination of the CG of equipped wing and fuselage, the moment equilibrium equation is made relatively to the fuselage nose (1.3).

$$m_f x_f + m_w (x_{MAC} + x_w^/) = m_0 (x_{MAC} + C) \qquad (1.3)$$

where m_0 – aircraft take-off mass, kg; m_f – mass of fully equipped fuselage, kg; m_w – mass of fully equipped wing, kg; $\boldsymbol{C}$ – distance from MAC leading edge to the CG point determined by the designer.

The position of MAC leading edge relative to fuselage nose may be calculated by formula (1.4).

$$X_{MAC} = \frac{m_f x_f + m_w \cdot x_w^{/} - m_0 C}{m_0 - m_w} \quad (1.4)$$

where m_0 – aircraft take-off mass, kg; m_f – mass of equipped fuselage, kg; m_w – mass of equipped wing, kg; C – distance from MAC leading edge to the CG point, determined by the designer.

$$X_{MAC} = \frac{111537.8 \cdot 32.125 + 179372.2 \cdot 2.615 - 289310 \cdot 2.51}{289310 - 179372.2} = 30{,}25m$$

C = (0,22...0,25) B_{MAC} –low wing ;

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

at X= 45° C = (0,32...0,36) B_{MAC}

Table 1.5

Trim sheet of equipped fuselage

№	Objects	Mass		Coordinates of CG	Moment (kgm)
		Units	Total (kg)		
1	2	3	4	5	6
1	Fuselage	0,0875	25314,625	34,72	878923,78
2	Horizontal tail unit	0,01152	3332,8512	60,29	200937,5988
3	Vertical tail unit	0,00877	2537,2487	60,29	152970,7241
4	Anti-icing system and air-conditioning	0,00975	2820,7725	34,72	97937,2212
5	Heat and sound isolation	0,0064	1851,584	34,72	64286,99648
6	Control sys 70%	0,0028	810,068	34,72	28125,56096
7	Hydraulic sys 30%	0,00381	1102,2711	48,608	53579,19363
8	Electrical eq, 90%	0,01575	4556,6325	34,72	158206,2804
9	Radar	0,0019	549,689	0,5	274,8445
10	Air-navig. system	0,0029	838,999	2	1677,998
11	Radio equipment	0,0015	433,965	1	433,965
12	Instrument panel	0,0034	983,654	2,5	2459,135
Passenger aircraft					
Passenger eq + Non typical eq + Additional equipment + Service equipment					
13	Onboard meal	0,0014189	410,501959	25	10262,54898

Ending of the table 1.5

1	2	3	4	5	6
14	Seats of pass.	0,0122	3529,582	34	120005,788
15	Seats of crew	0,00047	135,9757	3,3	448,71981
16	Seats of flight attendance	0,00037	107,0447	22	2354,9834
Furnishing (Lavatory, Galley/buffet)					
17	lavatory 1, galley 1, lavatory 2, galley 2 20%	0,00486	1406,0466	5,014	7049,917652
18	lavatory 3, galley 3, lavatory 4, galley 4, lavatory 5, galley 5 30%	0,00324	937,3644	20,42	19140,98105
19	lavatory 6, lavatory 7, lavatory 8, lavatory 9 20%	0,00324	937,3644	25,786	24170,87842
20	lavatory 10, galley 6, lavatory 11, galley 7, galley 8, galley 9 30%	0,00486	1406,0466	54,728	76950,11832
21	Non typical eq.	0,002	578,62	20	11572,4
22	Additional eq.	0,00805	2328,9455	18	41921,019
	Equipped fuselage without payload	0,19719	57049,3499	34,05927989	1943059,776
Payload					
23	Mail/Cargo	0,0518	14986,258	25	374656,45
24	Crew/attendant	0,00285507	826	20	226392,3078
25	Baggage	0,031301	9055,69231	25	16520
26	Passengers	0,09886	28160	34	957440
27	Monitors	0,00363	1600	34	54400
	Total	0,38515497	111537,8022	32,12452945	3583099,411

1.3.3 Calculation of center of gravity positioning variants

The list of mass objects for centre of gravity variant calculation given in table 1.6 and center of gravity calculation options given in table 1.7, completes on the base of both previous tables.

Table 1.6

Calculation of CG positioning variants

№	Name / Object	Mass, kg m_i	Coordinates CG M	Moment kgm
1	2	3	4	5
1	Equipped wing without fuel and LG	67018,6615	29,75334419	1994029,303
2	Nose landing gear (retracted)	1038,33359	7,82546683	8125,445067
3	Main landing gear (retracted)	9345,00231	34	317730,0785
4	Fuel	101970,203	32,6640057	3330755,293
5	Equipped fuselage	56499,3499	34,00545	1921285,818
6	Passengers	28160	34	957440
7	Baggage	10918,5594	25	272963,985
8	Cargo	16403,877	25	410096,925
9	Crew/attendant	826	20	16520
10	Nose landing gear (extended)	1038,33359	8,57076	8899,308
11	Main landing gear (extended)	9345,00231	36,34076	339604,4861

Table 1.7

Airplane's CG position variants

№	Variants of the loading	Mass, kg	Moment of the mass, kgm	Center of the mass, m	Centering
1	Take-off mass (LG extended)	289310	9404939,164	32,50817173	0,28763
2	Take-off mass (LG retracted)	289310	9382290,893	32,42988799	0,27765
3	Landing variant (LG extended)	200488,968	6355400,134	31,69950046	0,18448
4	Transportation variant (without payload)	236697,55	7777230,458	32,85724947	0,33216
5	Parking variant (without fuel and payload)	133901,347	4338688,262	32,40212551	0,2741

Conclusion to project part

Designed aircraft satisfies the planned aim of usage, its geometrical characteristics will provide the necessary aerodynamic performance, which will lead to efficient usage.

During the calculation the main geometrical parameters caused by operational purpose, planned quantities of passengers and cargo, speed and altitude of flight, conditions of landing and take-off, were considered. All obtained values meet requirements for the long-range passenger aircrafts.

The centering of the designed aircraft was performed. The most forward center of gravity position of equipped aircraft is 22.28% from the leading edge of main aerodynamic chord. The most aft center of gravity position of equipped aircraft is 34.92% from the leading edge of main aerodynamic chord. Between these values centering of the aircraft should be performed.

Geometrical parameters almost match with chosen prototypes. That fact allows to make a conclusion that designed aircraft will successfully compete with another models on the chosen market segment.

Furthermore, the engine Trent 800 that meets the requirements considering efficiency for designed aircraft was approximated. Main peculiarities of basic section of an aircraft and their influence on outline creation were figured out.

2. SPECIAL PART. DEVELOPMENT OF A NEW AIRCRAFT INTERIOR PASSENGER CABIN DESIGN WITH PANORAMIC VIEW.

2.1. Internal structure of the fuselage

The race to develop the most commercially successful and renowned passenger aircraft has shifted gears to focus on research topics closely pertaining to the fuselage. The fuselage is the most recognizable component of the aircraft and it refers to the long hollow tube which encloses the cargo and passengers along with the crew of the plane. The fuselage forms the center piece around which the aircraft structure is built. The fuselage structure has had to adapt with the changing times and working specifications, resulting in four major types – Truss structure, Geodesic construction, Monocoque shell, and Semi-monocoque fuselage.

1. Truss structure

A truss is a rigid framework made up of members, such as beams, struts, and bars to resist deformation by applied loads. The truss-framed fuselage is generally covered with fabric.

The truss-type fuselage fram**e** is usually constructed of steel tubing welded together in such a manner that all members of the truss can carry both tension and compression loads. In some aircraft, principally the light, single engine models, truss fuselage frames may be constructed of aluminum alloy and may be riveted or bolted into one piece, with cross-bracing achieved by using solid rods or tubes (fig. 2.1).

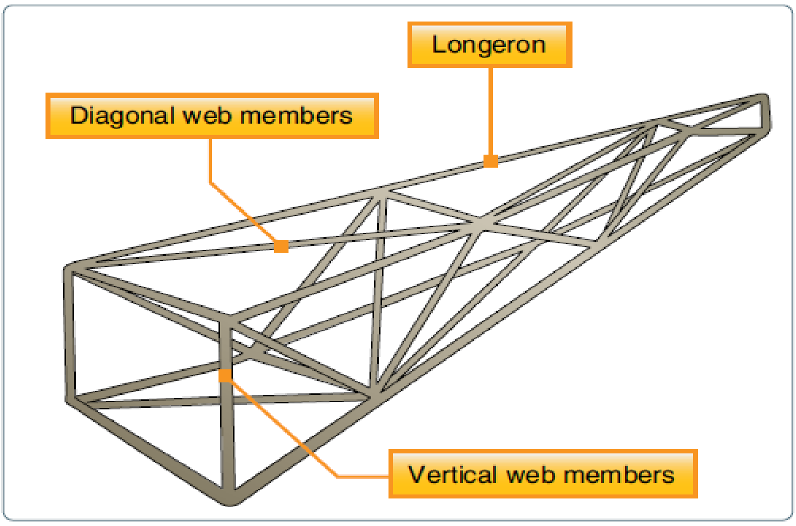


Fig. 2.1. Truss-type fuselage frame.

2. Monocoque Type

The true monocoque construction uses formers, frame assemblies, and bulkheads to give shape to the fuselage. The heaviest of these structural members are located at intervals to carry concentrated loads and at points where fittings are used to attach other units such as wings, powerplants, and stabilizers. Since no other bracing members are present, the skin must carry the primary stresses and keep the fuselage rigid. Thus, the biggest problem involved in monocoque construction is maintaining enough strength while keeping the weight within allowable limits (fig. 2.2).

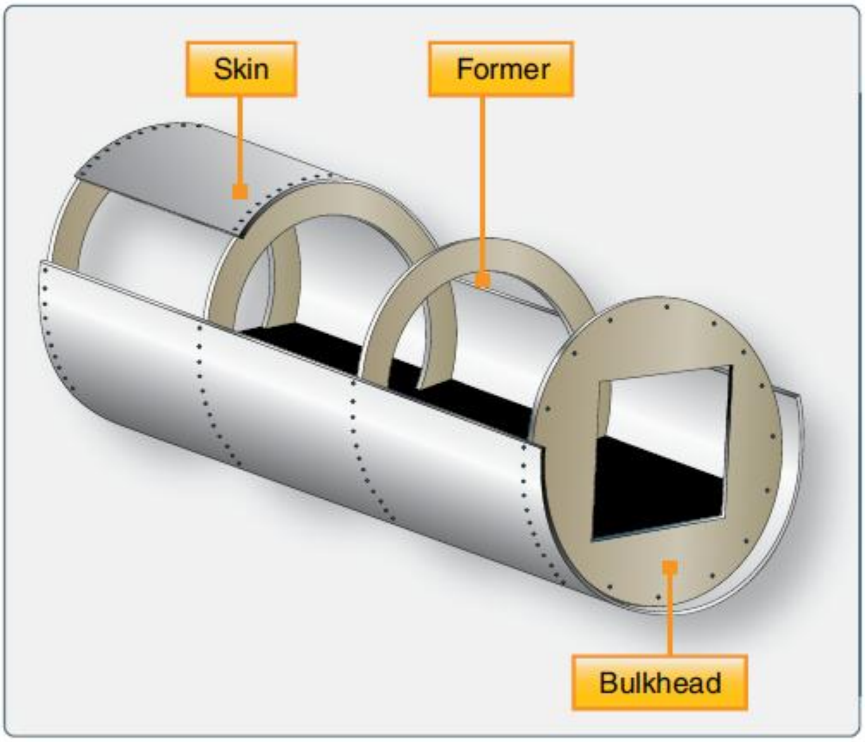


Fig. 2.2. Monocoque Type.

3. Semimonocoque Type

Semimonocoque construction, partial or one-half, uses a substructure to which the airplane's skin is attached. The substructure, which consists of bulkheads and/or formers of various sizes and stringers, reinforces the stressed skin by taking some of the bending stress from the fuselage.

Semi-monocoque: skin is stiffened by longitudinal elements (stiffeners, stringers, longerons). Stringers (6-10 in. spacing) increases skin stability, carry fuselage bending, provide multiple load paths for fail-safe design, Frames (~ 20 in. spacing).

The semimonocoque fuselage is constructed primarily of alloys of aluminum and magnesium, although steel and titanium are sometimes found in areas of high temperatures. Individually, no one of the aforementioned components is strong enough to carry the loads imposed during flight and landing. But, when combined, those components form a strong, rigid framework (fig. 2.3).

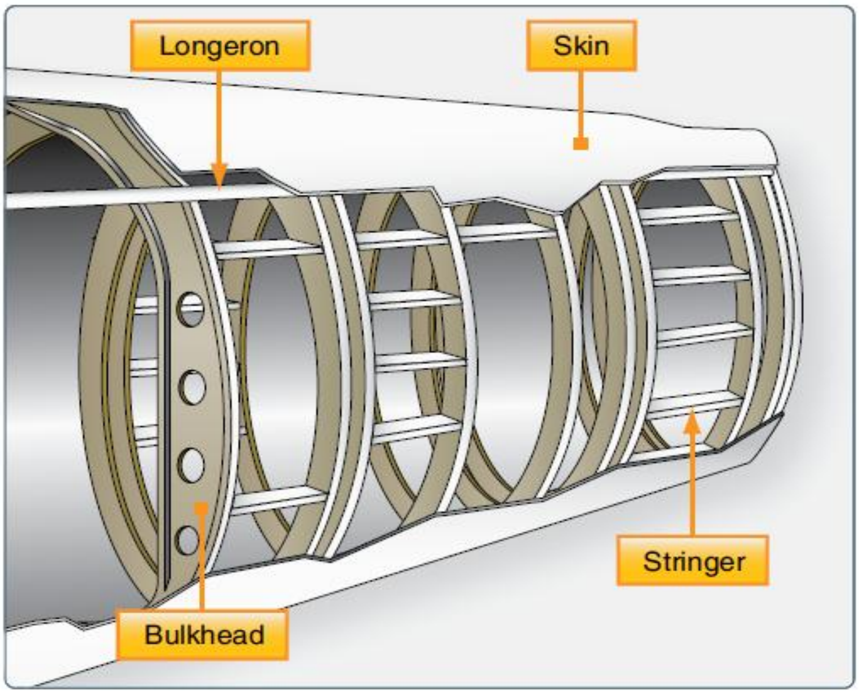


Fig. 2.3. Semimonocoque Type.

With the internal structure of the fuselage, everything is clear. Semimonocoque became most commonly adapted method of construction. But what about external view of the fuselage?

2.2. External view of the airplane

Modern aircraft fly at high speeds, which makes drag an important factor to consider. The reduction of drag can improve safety, efficiency and speed characteristics of an aircraft. So the engineers of the past came up with the next ideas to improve the design:

1. Nose part:
   a. The nose part should not be too “blunt”.

b. Local changes in the nose cross-section should be able to accommodate the windscreen panels in a safe and efficient way.

c. Windscreen angle should be a compromise between aerodynamics, bird-strike, reflection and visibility requirements.

a. Windscreen panel sizes should be less than 0.5 m^2 each (fig. 2.4).

Fig. 2.4. Embraer ERJ-145LU (EMB-145LU) - Swiss International Air Lines.

1. Tail Shape:

a. Smooth change in section required, from maximum section area to ideally zero.

b. Important parameter for determining tail upsweep angle is ground clearance required for take-off and landing rotation (fig. 2.5).

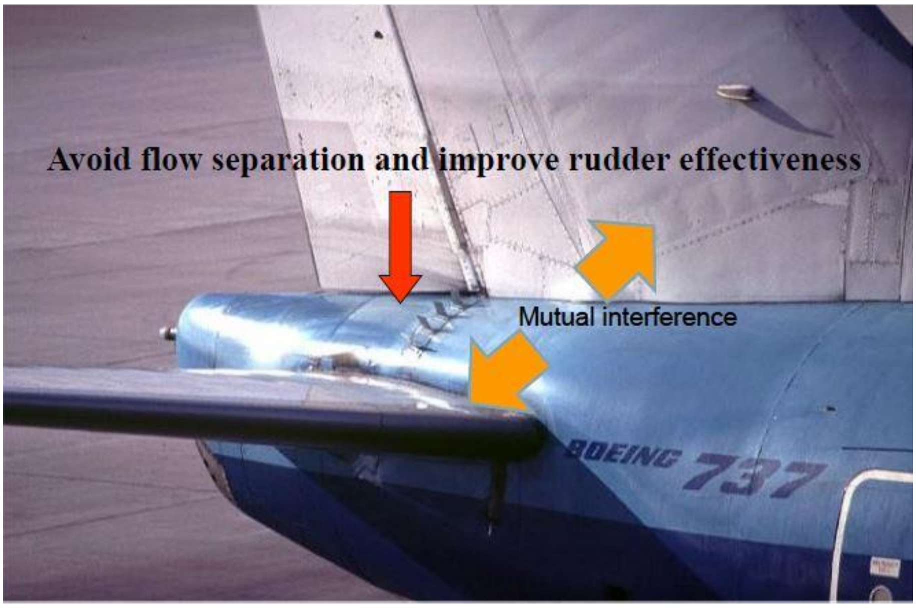


Fig. 2.5. Vortex generator at tail cone.

2. Was improved:
   a. Cockpit enclosure.
   b. Windshield.
   c. Fuselage length.
   d. Radome.

Thanks to these ideas, the cockpit enclosure, radome and windshield were improved, as well as fuselage length. But after all improvements there was still problem with vortex formation due to window flat panel (fig. 2.6).

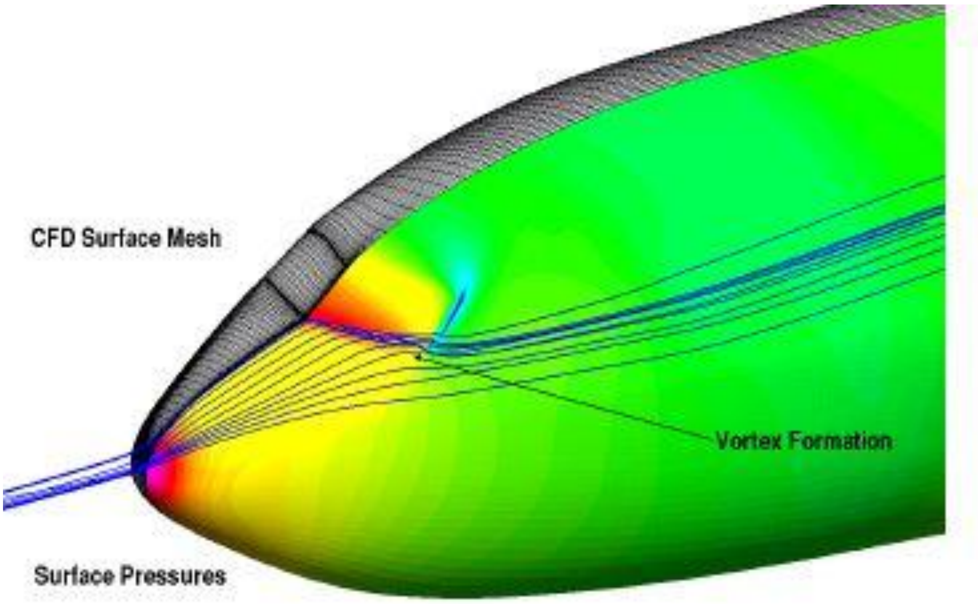


Fig. 2.6. Vortex formation due to window flat panel.

Windows were the weakest points not only in aerodynamic characteristics, but also in the aircraft strength.

2.3. Passengers windows

Some passengers are willing to give everything just to sit by the window on the plane and watch the clouds. From the window, the earth is visible at a glance: green patchwork quilts of landscapes, the wide expanse of the seas and the luminous lights of night cities: it is not surprising that seats near window are the most sought after (fig. 2.7).

Fig. 2.7. View from the aircraft window.

The window is not glass, but a double-glass, which can consist of 2-3 layers separated by an air gap. At the same time, two glasses are power, that is, capable of withstanding a pressure drops, at the same time. Thus, even damage to one glass does not threaten flight safety. The part visible to the passenger is a decorative plastic glass. It is much thinner than power and performs insulating and protective functions.

However, booking a window seat does not guarantee that you will have a window in your row. Instead, it may be a blank inner panel.

If you look at the fuselage from the outside, you can see that in some places on the plane there are windows missing.

In commercial aircraft designs, it is often necessary to provide space in special zones in order to ensure the structural integrity of the airliner.

Air conditioning ducts, wiring and other internal components can also be placed in such areas. This applies to all civil aircraft.

To paraphrase in simple terms, there are no windows in the place of the plugs because the structure is reinforced here so that the plane does not fall apart, or wires and air ducts pass through.

Passenger cabin windows are round or elliptical, since the corners are stress concentrators, which can lead to cracks and subsequent destruction of the fuselage structure.

The temperature difference in the cabin and outside is very large: inside the aircraft it is comfortable +25, and outside the window it can be -50 and lower.

A small hole of 0.5 mm in the inner glass performs an important function - through it the inter-glass air space communicates with the passenger compartment to equalize the pressure inside the glass package with the pressure in the cabin.

The window blind covers the window from the light coming from outside. It can be lowered during rest. During landing and takeoff, the window shutters must be open for safety reasons (fig. 2.8).

Many people ask the question: why are the windows in the aircraft rounded, and not square like ordinary windows or, for example, not triangular?

Fig. 2.8. Shape of the aircraft widow.

The answer is elementary simple. The very shape of the aircraft without corners, the rounded shape of the windows, as well as hatches and doors, is necessary for safety. Roundness allows you to evenly distribute the load from the difference in temperature and pressure, which prevents the occurrence of cracks, and subsequently depressurization of the cabin and rupture of the aircraft into pieces. In more scientific terms, it looks like this: when the plane is gaining altitude, the external pressure drops faster than the internal pressure - this creates a pressure difference inside and outside the aircraft, causing the body to expand.

When the body material changes its shape, stress is created in it. The material expands due to the fact that the stress is constantly increasing, eventually the stress reaches the limit that the material can collapse. In airplanes, the shape of the windows greatly affects the voltage level. The stress easily passes through the material without damage, if there are no obstacles such as a window in its path, in this place it needs to change direction, and this causes an increase in pressure. This is called stress concentration (fig. 2.9).

Fig. 2.9. Window cracks.

Comparing the effect of round and square windows on stress concentration, you can see that square windows create a greater barrier to the passage of stress. This means that stress is created at the corners of the square windows.

The limiting increase in the stress concentration causes the formation of cracks in the hull in these places. Such cracks led to tragic accidents until the study of destroyed aircraft made it possible to study the nature of the occurrence of stress in materials. That is, based on this, it becomes obvious why today the windows in airplanes are round, as well as all the bearing parts of the body, hatches, and doors are rounded.

The maximum increase in stress concentration causes the formation of cracks in the housing. But much more dangerous is the damage to the metal parts of the aircraft: in the window, broken by debris at high altitudes, will begin to suck all the loose things, and most importantly, passengers who did not have time to fasten (fig. 2.10).

In 2018, a Boeing-737 flying from New York to Dallas had its left engine exploded and shattered a window. The plane shook, panic began, and the 43-year-old passenger, who was returning from a business trip, was sucked into the window. The pilot made an emergency landing in Philadelphia, but could not save the woman. This is the first fatal incident in the past 10 years of operation of American carriers and the entire half-century history of Southwest Airlines. Even if no one is dragged into a broken window, due to lack of oxygen and extremely low temperatures overboard there is a risk and faint in seconds.

Fig. 2.10. Boeing-737 incident.

Therefore, instead of windows with glass, passengers will be asked to look at the sky and the ground behind the plane with the help of "virtual windows". Instead of using windows, the aircraft will use technology to show the external environment on the interior of the cabin through external cameras.

By removing all traditional openings, you can benefit from weight reduction, which means simpler construction, opening up a wide range of possibilities for interior design. There are no structural weaknesses in the construction of such a fuselage without windows. The plane is lighter, flies faster, higher, and consumes much less fuel.

But what about emergency situations? Hatches will be installed instead of windows to provide access and inspection to the passenger cabin.

2.4. Airplanes with panoramic "windows"

In the aircraft industry, as in any science-intensive industry, it sometimes happens that the same idea seems to be in the air. A project with this idea begins to be developed almost simultaneously, but independently of each other, by different companies.

In the second decade of the 21st century, the development of an aircraft project without windows, but with a panoramic view became such a priority concept. In 2012, they already tried to create a windowless cockpit, and Airbus in Paris presented the concept of an Airbus A320 liner with a transparent floor and a liner with broadcast monitors inserted into the walls of the cabin. The French, British and Americans are working tirelessly on their projects. Let's see what they do, and how soon we will be able to look at the world from a height of 10 thousand meters, without looking through the tiny windows (fig. 2.11).

Fig. 2.11. IXION Windowless Jet.

French studio Technicon Design won the Yacht & Aviation Award with the IXION Windowless Jet project in 2014. This is a business jet, the main idea of which is the complete absence of windows in the cabin. Instead, high-resolution flexible displays are placed on the inner walls of the fuselage, and several video cameras with a total viewing angle of 360 degrees are placed on the outside. The image from the cameras is broadcast on monitors, and the passenger of the airliner sees mesmerizing panoramic views. Blurring the boundaries between the aircraft and the surrounding space, full involvement in the dynamics of the flight - this is what the company strives for.

According to the most careful estimates of the designers, a real IXION business jet may appear no earlier than in 10-15 years (fig. 2.12).

Fig. 2.12. Windowless fuselage.

The British company Center for Process Innovation (CPI) in the same 2014 presented its project for a promising future in passenger air transportation. Flexible displays will also be able to display ambient views from outdoor cameras or act as lighting panels with light intensity depending on the time of day. High-definition OLED screen technology is still imperfect, and the full implementation of the concept should be expected by about 2035.

Fig. 2.13. S-512 Quiet Supersonic Jet.

The American company Spike Aerospace is still ahead of the rest and is already implementing the S-512 jet, which will fly in the direction of London - New York with an average speed of 1770 km / h (maximum 2200 km / h) and with a carrying capacity of up to 18 passengers. Nearly 2.5 times bigger than normal speed of an airliner requires an integral fuselage structure. This increases flight safety, and in this case it is the priority reason for abandoning windows in favor of monitors. Tests of the demo model SX-1.2 took place on October 7, 2014 in the United States. A full-fledged prototype S-512 Spike Aerospace plans to test no later than 2024, and begin mass production from 2026.

Fig. 2.14. Spike Aerospace Jet.

Disadvantages:

1. The initial investment is high.
2. Because the external environment is very aggressive to cameras, it would need constant maintenance and could present problems during flight causing discomfort to passengers (fig. 2.15).
3. The cameras may interfere on aerodynamics aircraft;
4. It can be uncomfortable for some people the appearance of a transparent plane, as if outdoors, especially those afraid of heights.
5. If a person wants to sleep during the flight, may feel troubled with lights, even though turn off the screen next to it, the whole aircraft can be illuminated.
6. Flying in an airplane without windows seems strange to many people, especially for those claustrophobic.

Fig. 2.15. Fig. 2.12. Windowless Jet.

Advantages:

1. Ability to use less powerful engines due to decreased drag.
2. Reduction in the price of this component, engine.
3. Fuel consumption is reduced.
4. Less CO_2 emission.
5. Resulting costs for companies fall, and consequently for passengers, too.
6. The elimination of windows increases the strength of the fuselage.
7. The plane becomes lighter, the calculation of fuel is less, the flight is cheaper.
8. Without windows, the aircraft body is easier and cheaper to manufacture.
9. Any view can be projected onto displays, not necessarily the one that surrounds at the moment - it can be mountains and deserts, city lights and even a view of the Earth from space (fig. 2.16).
10. Energy-saving technologies - monitors use low voltage electric current.

Fig. 2. 16. Aircraft with panoramic view.

2.5. Monitors

Flexible LED screen is made up of LED pixels pitched on a pliable material like rubber or PCB. It is insulated using a flexible transparent material on both sides to protect the LED circuit from getting damaged. This structure makes flexible LED screens highly resilient. They can be contorted during installation and still deliver crisp images. [11]

A flexible video wall consists of many foldable LED screens mounted together. It can take different shapes depending on how the individual screens are arranged. The flexible LED screen display panels are joined using magnets along their borderlines to create a seamless video wall display (fig. 2.17).

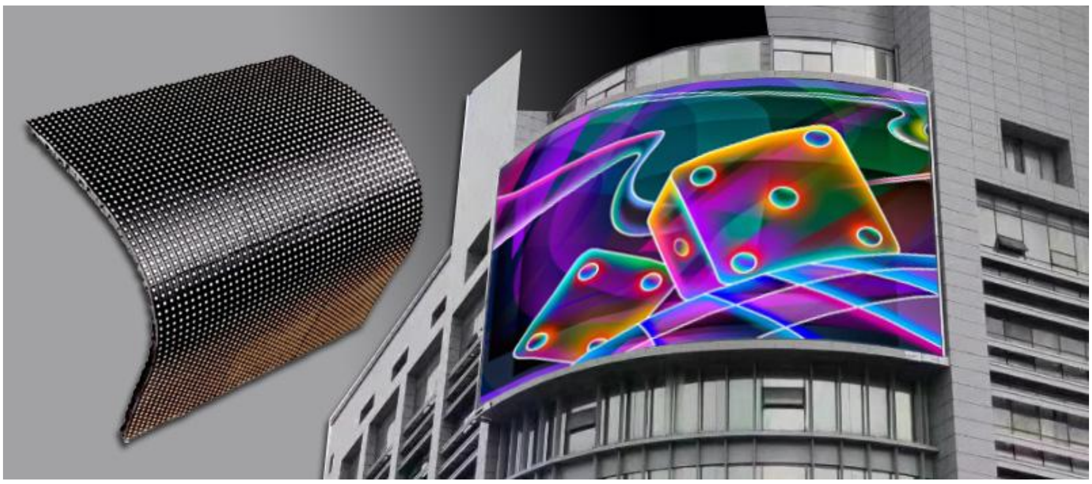


Fig. 2.17. Flexible LED screen for the outdoor advertising.

Flexible display features

1. In the production of flexible screens, high-quality LEDs are used, which are installed on a special module, showing a bright and clear image, like a regular LED screen.[12]
2. With a refresh rate of more than 1200 Hz, the image does not flicker, suitable for professional use.
3. The module is flexible, making it suitable for all kinds of irregular shapes such as circles, columns, ellipses, triangles, etc (fig. 2.18).

Fig. 2.18. Different shapes of the screen.

Advantages:

1. Any screen size and shape.

The LED screen is assembled from modules, and therefore can have any size, aspect ratio and shape.

2. Easy content management (fig. 2.19).

Screen monitoring and content management via Wi-Fi and LAN.

3. High maintainability.

If one module fails, the screen will continue to work. A defective module can be easily replaced with a new one.

4. The ability to combine the broadcast image with lighting effects.

5. The ability to work in adverse weather conditions.

6. The ability to quickly replace any diode when it burns out.

7. The ability to broadcast both dynamic and static images.

8. High image quality, rich colors, excellent brightness, high contrast ratio, large viewing angle.

9. High efficiency, both in the daytime and at night;

10. Low weight (eight times lighter than conventional screens), ease of assembly, installation and dismantling.

11. Displays do not require frequent maintenance.[13]

Fig. 2.19. Monitors in passenger compartment

2.6. Strength analysis

For the better understanding of operation of the passenger cabin with and without windows under operational loads solid modeling of the frame was carried out by software SolidWorks 2020 with subsequent strength analysis. For the analysis were taken passenger cabin with length 36.3 m, diameter 6.3 m and 2024T3 aluminum material. The pressure equal 50662.5 N/m^2 was applied. Analysis is shown in the following figures (fig. 2.20-2.25).

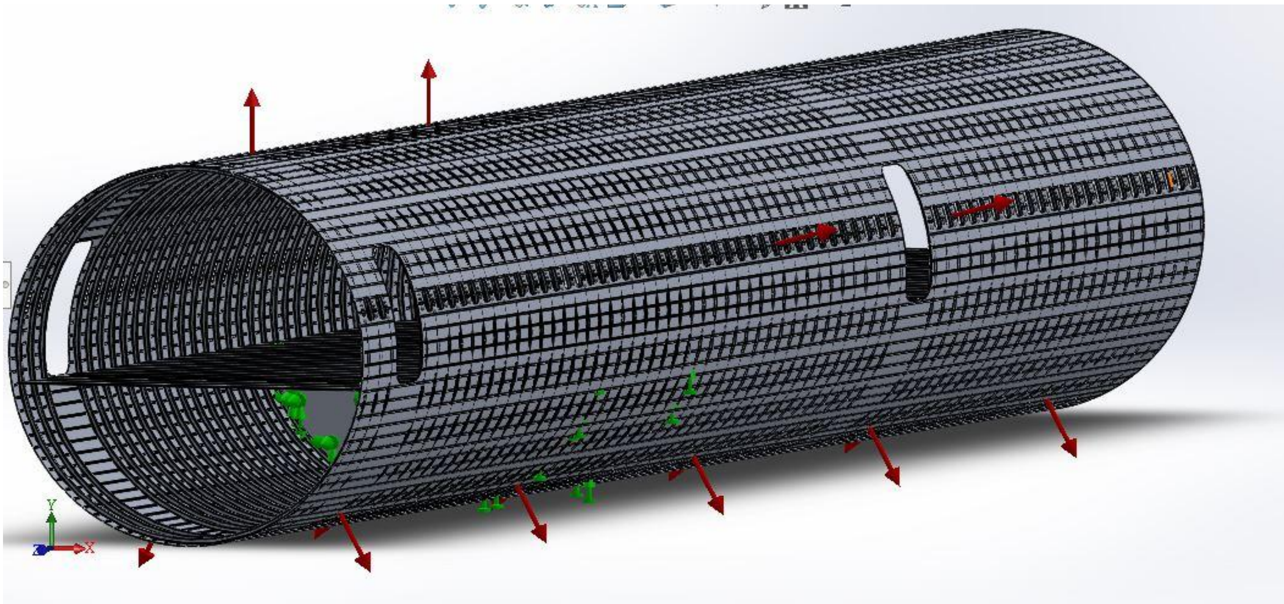
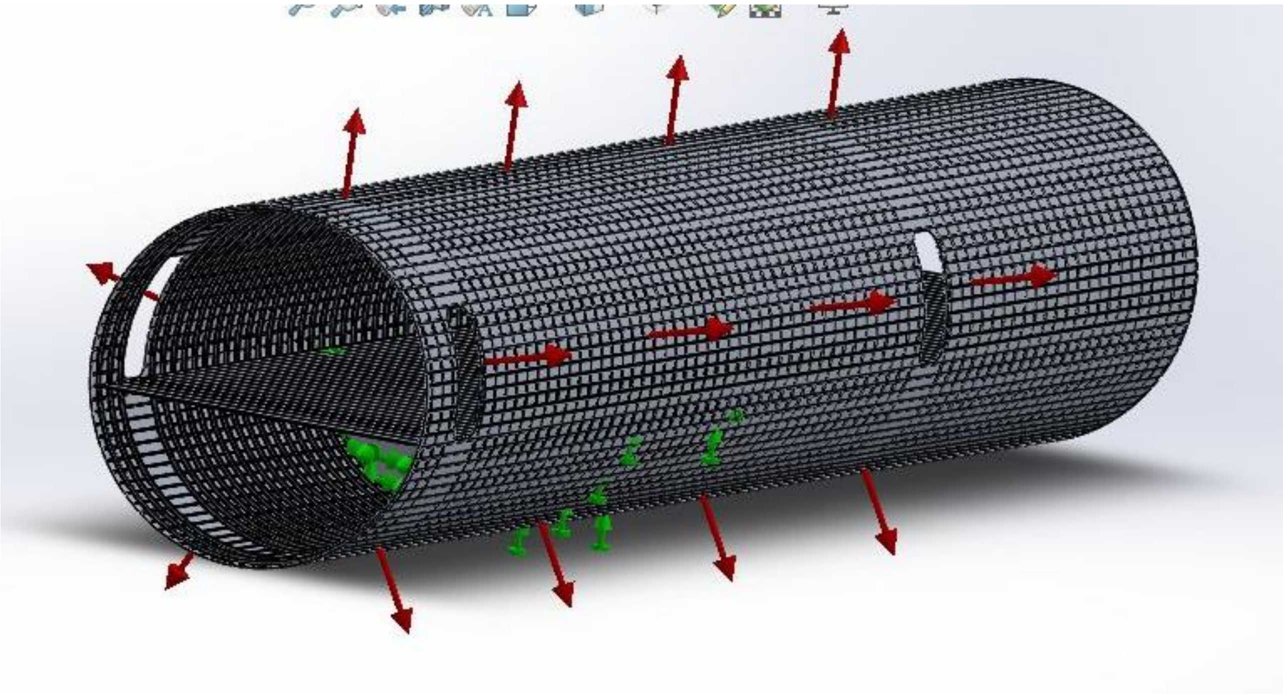
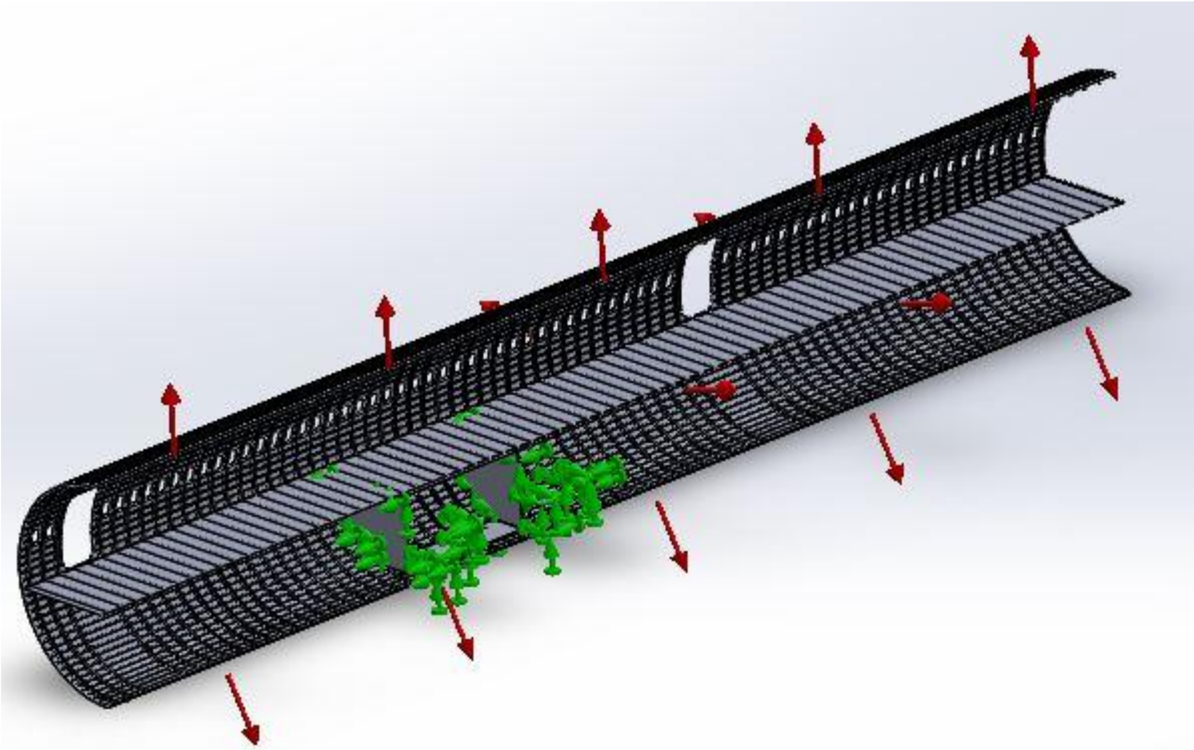


Fig. 2.20. Load application to the fuselage with windows



. Fig. 2.21. Load application to the fuselage without windows



. Fig. 2.22. Load application with windows cross-section

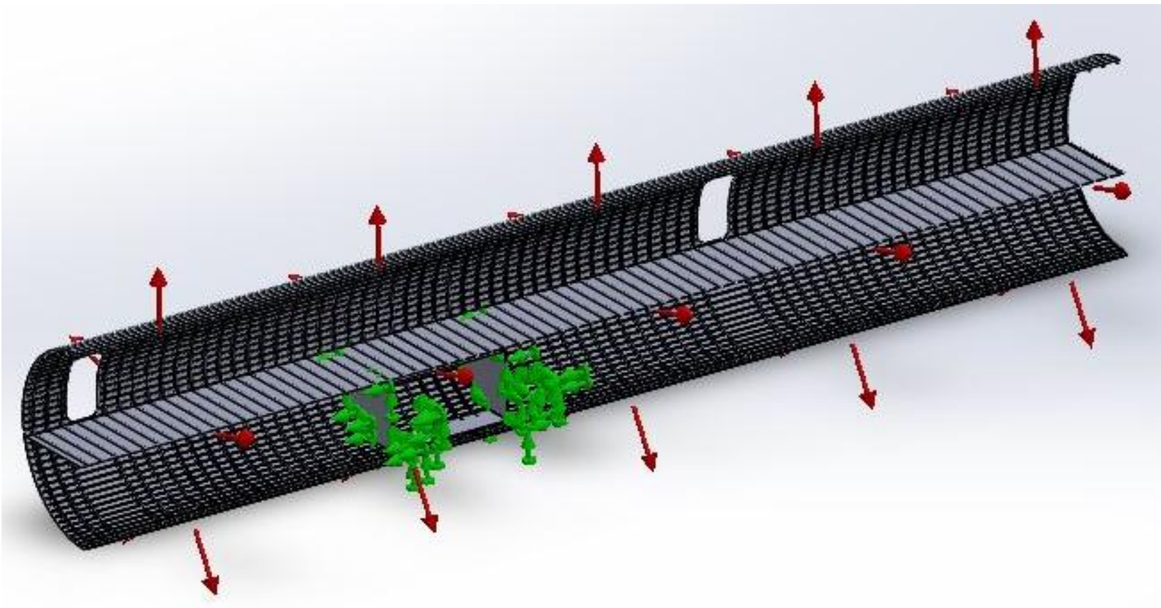


Fig. 2.23. Load application without windows cross-section

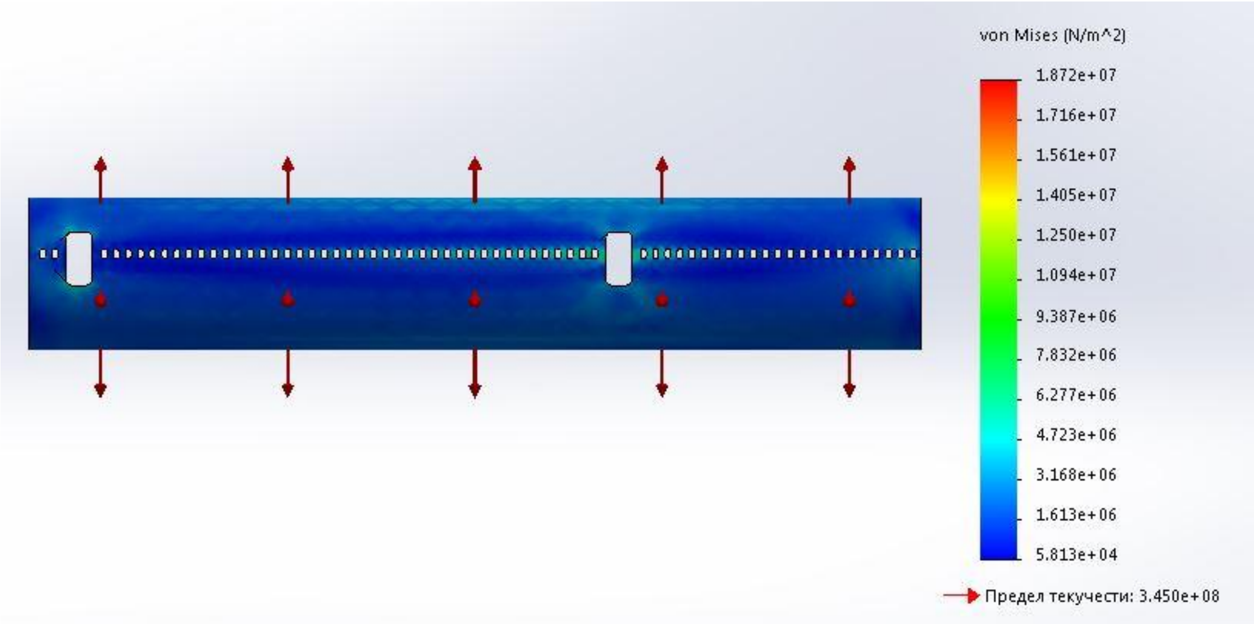


Fig. 2.24. Diagram of the stress distribution with windows

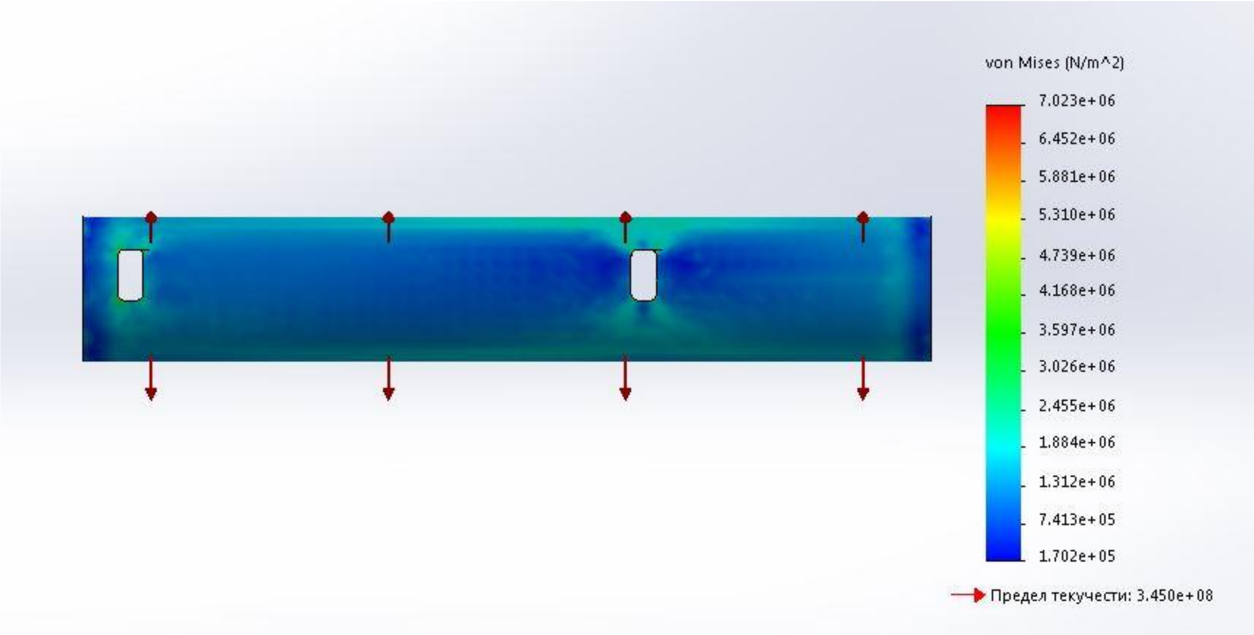


Fig. 2.25. Diagram of the stress distribution without windows

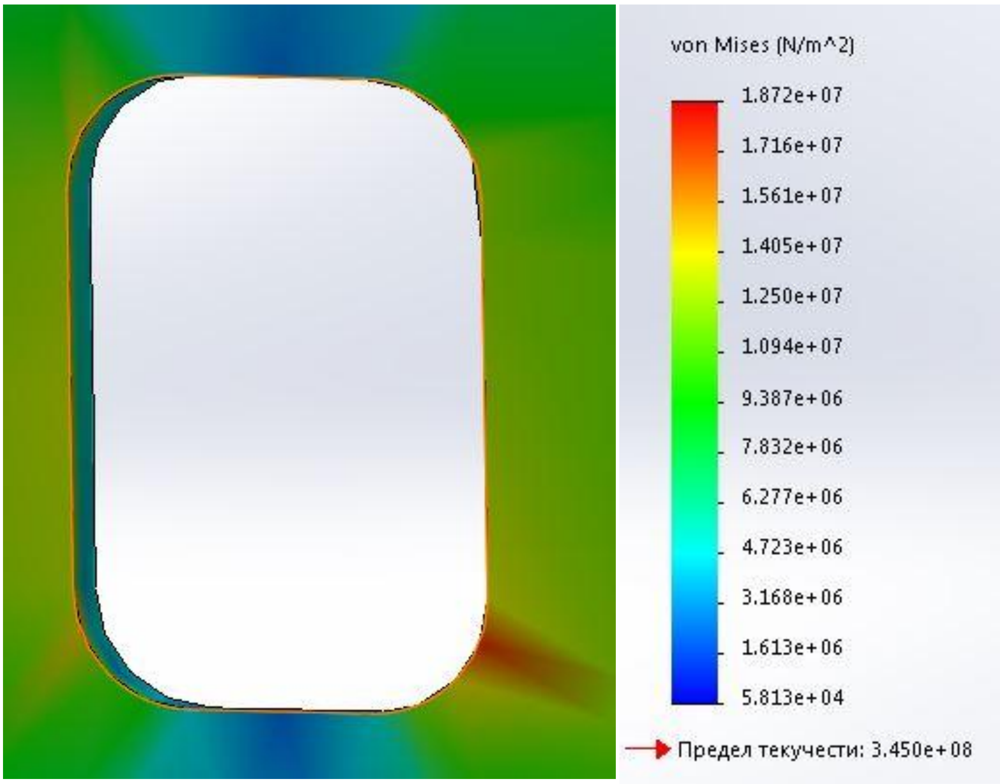


Fig. 2.26. Window - most stressed points

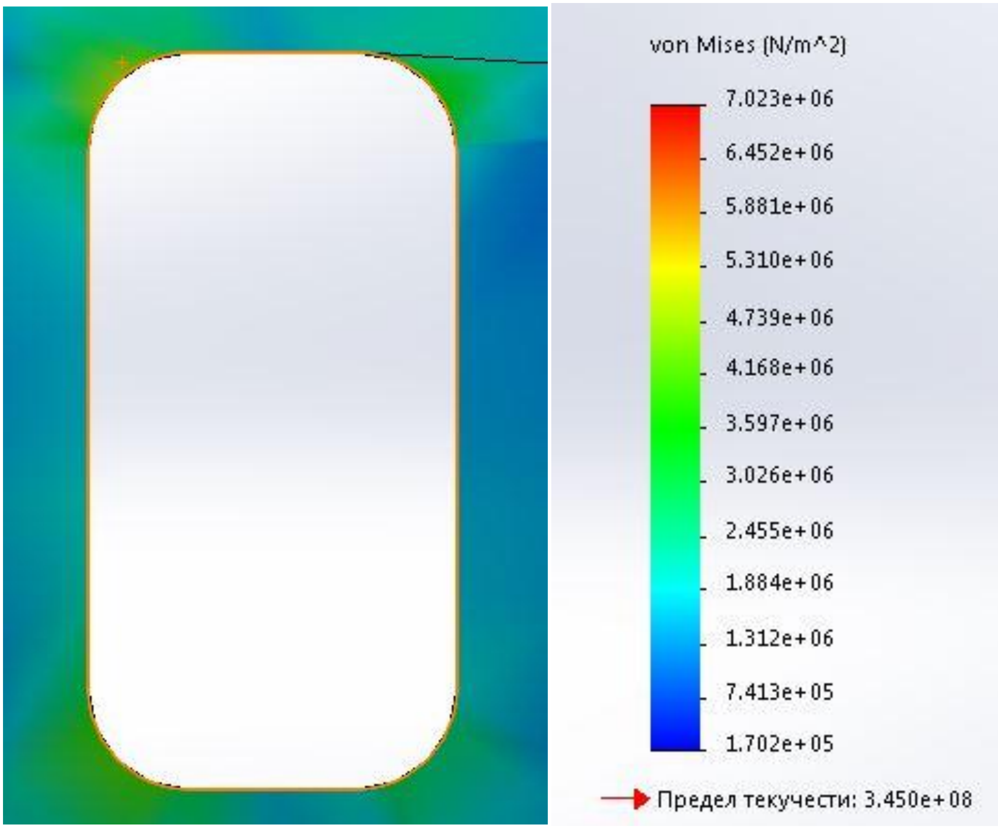


Fig. 2.27. Door - most stressed points

According to the performed strength analysis of the passenger cabin with and without windows the maximum stress that acts in it during flight is equal to 18.72 MPa and 7.02 MPa respectively, which is shows that passenger cabin without windows is 38% stronger. So it may be concluded that it is strong enough and can carry all operational load better that passenger cabin with windows.

Conclusion to the Special Part

Over the years, the external and internal appearance of the fuselage has changed many times. All changes have been made to improve certain characteristics of the aircraft. But now it is time to improve the design once again. Modern technologies, such as progressive flexible screens, allow to open new ways to improve the fuselage characteristics. Flexible screens can be installed instead of conventional windows, giving a lot of advantages. The progressive screens have more options and can completely replace the weak points of the fuselage.

3. ENVIRONMENTAL PROTECTION

3.1 Introduction

In the past, nobody really cared about the pollution produced by an aviation industry. It greatly affected the nature and health of humans, and a huge hole in the Ozone layer emerged. Only then governments started to discuss this problem and try to solve it. People, tired of living in polluted cities and seeing how the nature dies, would not let this continue. The problem of ecology became a popular topic for discussion in society. So the governments of many countries now had to make the laws and force manufacturers to produce more eco-friendly products to reduce the damage of aviation industry on the environment. And so began the times of change, where the ecology became a priority. The pollution dropped, Ozone layer almost healed, and new, more efficient designs were developed. The desire to protect the planet and improve the technology even more is strong nowadays.

Today, almost everything related to civil aircraft world must be under control of the International Civil Aviation Organization (ICAO). ICAO creates basic requirements for the operation of civil aircraft. It also includes the requirements to certify the plane based on how damaging to environment or eco-friendly it is. If the company produced an aircraft that do not meet ecology standards, it means that it will usually be banned to fly in most applications (we do not count military and special tasks here). But what about dealing with the damage that has already been done to the nature? Who will pay for that? ICAO almost does not deal with these issues. Each state has to decide this on their own. ICAO's job is to be an international platform for cooperation and discussion of environmental protection problems related to the aviation industry. A lot of countries participate in ICAO and follow its regulations under the Chicago Convention. These countries are called ‘ICAO Member States’. To be more effective, these states decided that they should focus on 3 main problems:

1. Climate change and aviation emissions.
2. Aircraft noise.

3. Local air quality.

So all countries together develop new global aviation standards, that comply with ICAO, to meet these objectives. Additionally, it was decided to set the aspirational goals for international aviation, and to prioritize ICAO's environmental protection standards on:

1. Airframe, engines, and other technical aviation inventions and innovations.
2. Optimizing flight procedures to reduce fuel consumption.
3. Increasing the production and implementation of bio-made fuels and clean energy (electric, wind, solar).
4. Implementing the Carbon Offsetting Reduction Scheme for International Aviation (CORSIA).

But what about electromagnetic pollution from many airplanes flying today?

3.2. Electromagnetic Radiation

In modern conditions, it is important to protect against electromagnetic field (EMF) radiation. Sadly, the modern technical progress inevitably creates EMF impact on population and surrounding living nature. This is connected not only with the growth of the number of EMF sources, but also of their spheres of application.

The spaces of modern populated areas are full of electromagnetic radiations of various ranges, which is caused by the operation of technical devices, such as phones, transmitting towers, and different infrastructure, like wire towers or transformers. Concentration of electromagnetism in the environment constantly increases, taking the form of general electromagnetic pollution. There can even be a noise pollution near high-voltage electric lines. In recent years, environmental pollution from EMF increased more than tens of thousands of times, reaching of a global nature and exceeding in importance the impact of chemical and radiation factors, and it tells a lot (fig. 3.1).

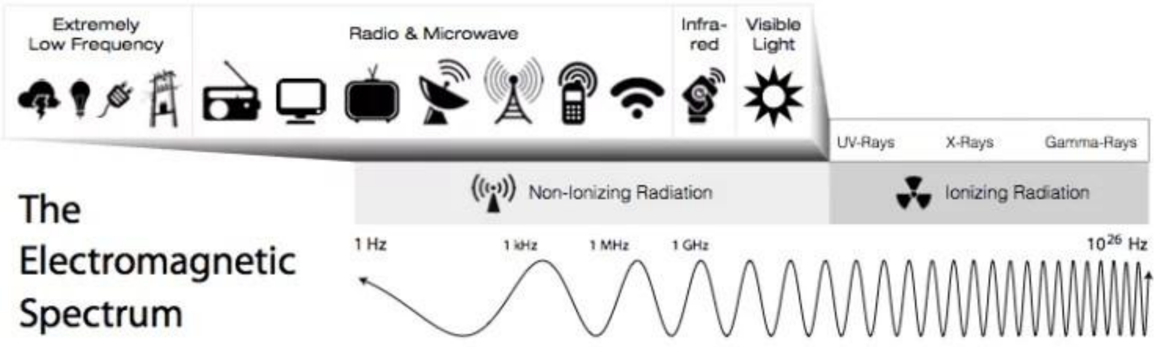


Fig. 3.1 The Electromagnetic Spectrum

In the era of scientific and technological progress, the more and more uses of artificial EMF sources are created every day. The influence of EMF can lead to biological damage of anthropogenic origin. EMF significantly exceeds the natural factors influence, and is the unfavorable factor that affects a person and the environment, growing year after year. [15]

Some of the types of technogenic sources of EMF should be discussed in more detail.

1. Power transmission lines.

The wires of the working power transmission line create electric and magnetic fields of industrial frequency near them. These fields can extend from the wires of the line to tens of meters.

The range of propagation of the electric field depends on the voltage class of the transmission line (the number indicating the voltage class is in the name - for example, a 220 kV transmission line). So, the higher the voltage, the larger the zone of increased electric field level. But once the power transmission line starts the operation, the size of the zone does not change.

The spread of the magnetic field depends on the magnitude of the current flowing or on the load of the line. Load depends on number of users and the combined power output needed by these users.

2. Household electrical appliances.

Modern homes are packed with electronic devices. The most powerful of this group of EMF sources should be recognized as microwave ovens, air grills, refrigerators with a frost-free system, kitchen hoods, electric stoves, TVs, computers. Depending on the specific model and mode of operation, the actually generated EMF can vary greatly among equipment of the same type.

Yes, the greatest radiation of the computer comes not from the monitor, but from the back wall. Contrary to the established opinion that EMF is not generated by laptops, its source is not electron beam tubes and liquid crystal screens, but voltage converters, control circuits, devices that form information and other elements of equipment. All given data refers to the typical magnetic field for home appliances - 50 Hz.[6]

The values of the magnetic field are closely related to the power of the device - the higher it is, the higher the magnetic field during its operation. The value of the electric field of the industrial frequency of almost all electrical household appliances does not exceed several tens of V/m at a distance of 0.5 m. The growing variety of household appliances inevitably leads to an increase in the dose electromagnetic radiation the inhabitants of such a household experience[7].

3.3. Aviation Electromagnetic Radiation

Modern aircrafts are packed with various electronic gadgets more than spaceships in the 80s movies. The radio communication systems, navigation equipment and both ground and airborne radars are a source of significant flows of electromagnetic energy.

Due to the nature of all these devices, the environment around them is under influence of many-many electromagnetic frequencies, varying in power, operation modes and levels of radiation. So it is clear that such objects can irradiate not only people near aircraft or operators in airport, for example, but also everybody in the nearby settlements, farms, forests etc.

The sources of high-frequency electromagnetic radiation are one of the most dangerous. Here is the list of the devices that can create such radiation:

1. External and internal radio equipment (radiostations on the ground and in the air)
2. Radio navigation equipment (radars in the nose of aircraft, Doppler radars, radio altimeters, radio compasses, radio distance meters);
3. Radio equipment of aircraft landing systems (survey, control and landing radars, radio direction finders, radio beacons).

Because all this equipment emits a lot of electromagnetic energy in the NPS, the formation of electromagnetic fields (EMFs) of high intensity is possible. I believe it is not necessary to describe which effect it has on environment and living beings. But, just in case:

When the electromagnetic waves are interacting with a living organism,they partially reflect, which is not that bad, but they also partially propagate in those beings and get absorbed. So ho bad is this influence? It depends on the amount of energy absorbed by the tissues of the body, the frequency of the waves and the size of the living being affected.

Such absorption of electromagnetic energy leads to the significantly increasing temperature of tissues. There are some organs in the human body that have a poorly expressed mechanism of thermoregulation (brain, eyes, kidneys, gall bladder). This leads to their increased sensitivity to electromagnetic radiation.

3.4. Airplane Electromagnetic Radiation

There is no safe place to hide from EMF radiation. It is present both on the ground and when flying high in the sky. So we are at increased risk of exposure to EMF everywhere. The skies may look as clear as spring water, with some clouds coming and going from time to time, but it is important to know that there are over 44,000 flights a day, carrying 2.7 million people. This surely pollutes the skies with EMF radiation.

But it would not be possible to get rid of EMF radiation entirely, even if we somehow invented the aircraft with no electronics and left all our gadgets in the airport. Flying itself exposes us to higher levels of cosmic radiation than while we travel on the ground. The Center for Disease Control and Prevention even classifies airline crew members as radiation workers, can you imagine that?

Let’s take a look at how flying in the “metal bird” can actually increase the EMF radiation exposure of its passengers.

Airplanes are truly packed with electronics. Within a plane, there are countless sources of EMFs: the cockpit and communications equipment, engines, electrical wiring and sensors, Wi-Fi, artificial lighting, headphone ports, all your gadgets like phones laptops etc., and even static electricity in the fuselage. But the number of EMF sources is not the only problem. The emissions created due to something called the Faraday Cage Effect is another problem.

Planes have a metal mesh built into their walls all over the aircraft to deflect lightning. So the airplane becomes sort-of a Faraday cage, which is a metal cage that surrounds an object to exclude electrostatic and electromagnetic influences. It is not a perfect Faraday cage because of the communication antennas and the windows, which create small holes in this "cage".

When a plane is hit by lightning, the charge hits the metal and travels along the exterior of the plane, discharging itself in the process. Then it strikes the ground without harming passengers or equipment. Plus, the equipment is additionally heavily protected from this.

However, just as Faraday cages keep electromagnetic activity outside the plane, it also keeps EMFs inside.

Being inside this cage only increases the effects of EMF radiation, because it traps the emissions inside. The windows allow for some EMF radiation to leak out (which is why you can have a weak cell phone signal while in a plane still on the ground), but it is not enough. The overall structure makes the EMF environment inside airplanes a safety concern[14].

Wi-Fi on board airplanes

Due to the Faraday Cage Effect, Wi-Fi is one of the main sources of EMF radiation that can impact the aircraft passengers.

Many airplanes are equipped with Wi-Fi hotspots to allow you to stay connected to the network, even during long flights. However, the exposure to Wi-Fi in such circumstances can be harmful, no matter where you are connecting.[15].

There exist two ways in which the in-flight Wi-Fi works: ground-based mobile broadband towers or satellite technology.

Towers on the ground send signals up to the aircraft’s antennas, which are located on the bottom of the fuselage. As the plane travels, it connects to the nearest towers so that the signal is maintained. Issues with this type of Wi-Fi can occur when travelling over remote areas, such as deserts or oceans, as there are no towers to connect to.

The second way Wi-Fi works onboard is by connecting to satellites that are in geostationary orbit (35,79 kilometers (22.24 miles) above the ground). The plane and satellites communicate with signals sent via receivers and transmitters. The antennas on the top of the aircraft distribute the signal to passengers using a router [16].

A lot of major airlines keep up with modern reality and are equipping their planes to provide Wi-Fi for their passengers. A 2018 survey conducted by RouteHappy, the industry leader for evaluating in-flight amenities, found that 82 airlines now offer onboard Wi-Fi and nearly half of all seat miles worldwide offer the chance to connect while flying.

Depending on the size of an aircraft, there can be hundreds of other passengers in the same flying metal tube as you. Nowadays, almost everyone has at least one electronic device (i.e. a smart phone) and many will fly with more to keep them entertained, perform work or study, whether its a laptop, kindle, tablet, phone, or portable gaming device.

All of these devices emit EMF radiation. The longer the flight, the longer is the exposure to the EMF radiation in high quantities.

Usually, if the distance to the source of EMF is 1 feet (30.5 centimeters) away, emissions drop by 80%. On the distance of 4 feet (122 centimeters) from EMF source, emissions drop by 98%. While the last one is usually a safe distance, in the confines of an airplane, it might not be possible to create this much distance, and the Faraday Cage effect can affect the drop of EMF emissions in a negative way.

Additionally, aircraft receive cosmic radiation from the atmosphere. And airplanes have the added complexity of electromagnetic fields (EMFs) bouncing around inside the fuselage.

To summarize, the EMFs exist in things like communications equipment, cockpit computers, and electrical sensors. The EMF exposure to passengers is amplified by the metallic structure of the plane, which traps and therefore intensifies the fields [17].

3.5. Environmental Protection Law

To reduce electromagnetic pollution, the government of Ukraine adopted an order, in which the State sanitary norms and rules for working with sources of electromagnetic fields are approved.

1. General provisions

1.1. State sanitary norms and rules when working with sources of electromagnetic fields (they will be mentioned in this article as “sanitary standards and rules”) establish requirements for the working conditions of employees that take part in production, operation, maintenance and repair of equipment, during the operation of which there are permanent magnetic fields (referred in this article as EMF) and electromagnetic radiation (also referred as EMF) in frequency range from 50.0 Hz to 300.0 GHz.

1.2. These sanitary norms and rules do not apply to workers working with visual display terminals electronic computing machines or perform work in not turned off electrical installations up to and including 750 kV.

1.3. Sanitary norms and rules are mandatory for everyone ministries, other central executive bodies, enterprises, institutions, organizations regardless of the department ownership and forms of ownership, citizens who design, manufacture, operate and service equipment, apparatus, devices, equipment, etc., which are sources of EMF, which develop and implement measures to reduce the harmful impact of EMF on workers who perform state sanitary supervision of conditions labor

1.4. The requirements of these sanitary norms and rules must be taken into account in regulatory and technical documents: standards, building regulations, technical conditions, instructions, methodical instructions and others that regulate constructive and operational requirements for equipment, equipment, devices, devices, etc., including those of foreign production, which are available EMF sources.

1.5. There must be industry (departmental) normative documents brought into compliance with the requirements of these sanitary norms and rules.

1.6. Sanitary norms and rules when working with EMF sources prepared taking into account the results of new scientific research this field.

5. General requirements for measurements and hygienic assessment of research results.

5.1. Evaluation of the levels of action of permanent magnetic fields, as well as variable EMF in the frequency ranges of 50 Hz, 1 kHz - 300 MHz is carried out by measuring the intensity of the electric and magnetic components of the EMF, in the frequency range of 300 MHz - 300 GHz - by measuring the SPE, taking into account the time spent by personnel in the radiation zone.

5.2. Sanitary and hygienic studies of EMF levels at workplaces are carried out by sanitary laboratories of enterprises and organizations certified by the certification commission of the Ministry of Health of Ukraine, as well as institutions and establishments of the state sanitary-epidemiological service of Ukraine.

5.3. If the installation has several operating modes, that each differ in generation parameters, type and placement of working elements or radiating systems, etc., then the measurement is carried out in each mode at the maximum used power.

5.4. Measurements of the RF radiation of rotating and scanning antennas are carried out when the antenna is stopped in the direction of the maximum radiation at all operating values of the tilt angle. For an open area with a uniform relief, the results obtained for one direction of radiation can be spread over the entire sector captured by the antenna during its movement in the radius on which the measurement was carried out. In cases characterized by heterogeneous topography, the presence of buildings and other structures, it is necessary to conduct measurements at workplaces and in places where personnel may be present when the radiation is directed at the measurement location.

5.5. If the employee's workplace may be exposed to several operating installations at the same time, its intensity must be estimated for each of the measured sources.

6. Requirements for production premises and equipment location

6.1. Premises that house installations that are sources of EMF, must meet the requirements of current sanitary standards regarding the design of industrial enterprises. Also, according to their planning decision, they must correspond to the nature of the technological processes performed in them. The levels of heating, ventilation, and lighting of the premises must meet the requirements of building regulations and rules. Meteorological conditions in the premises, presence in the air working zone of harmful substances, noise level, as well as others adverse factors of the production environment must meet the requirements specified in the relevant regulatory documents approved by the Ministry of Health of Ukraine.

6.2. There exist 2 types of places where the equipment that is a source of EMF, depending on construction, purpose, power and conditions of use, can be placed. It can be placed in some specially designated rooms, or in general rooms, including placement in current lines. But for both these places, the compliance with the requirements of section 4 of sanitary norms and rules is required.

Additionally to these sanitary norms and rules, when placing the equipment and organizing work related to it service, it should also be guided by:

1. Building regulations and rules;

2. Rules for arranging electrical installations;

3. Rules for the technical operation of consumer electrical installations and safety rules for the operation of consumer electrical installations.

4. Protective equipment must meet the requirements of the regulations use and testing of protective equipment used in electrical installations.

6.3. When placing several installations in one room, it is necessary to make it impossible to exceed the GDR when summing up the radiation energy.

6.4. In case of possible passage of electromagnetic energy through building structures into neighboring premises, the measures must be taken to ensure that the workers are not exposed to it at levels that exceed the maximum permissible level for the relevant categories of exposure.

6.5. Allowed upon agreement with state authorities sanitary-epidemiological supervision of works related to adjustment and regulation of equipment that is a source of EMF in shielded rooms. To receive the desired effect and comply with safety requirements when working with high voltage and sanitary norms of the design of industrial enterprises, the working areas and volumes of shielded premises should correspond to actual dimensions of the processed products. The EMF can be brought to acceptable levels by covering the walls, ceiling and floor of shielded premises with materials that absorb EMF.

This will make it impossible to exceed the GDR due to reflected radiation if the level of absorption of EMF will be sufficient.

In the case of directional radiation, the use of absorbent coatings is allowed only on the corresponding sections of the walls. In screened rooms, measures should be taken in accordance with the requirements of sanitary norms and rules to compensate for the lack of ultraviolet light, changes in the gaseous and ionic composition of the air, lack of natural light etc.

Conclusion to the Environmental Protection Part

Transport is one of the most important branches of public production and is designed to meet the needs of the population and public production in transportation. At the same time, transport is one of the main polluters of the natural environment.

Until recently, questions about the impact of aviation on the environment and human health occupied an insignificant place in the general discussions devoted to the problems of environmental protection. But it all changed recently. As society's awareness of the importance of environmental problems and concerns about ways to solve them pushed the governments of countries all over the globe to create laws and practices that reduce the impact of aviation on nature. Therefore, recently, environmental issues in air transport processes have attracted much more attention than it was before. An open desire to preserve and improve the currently achieved levels of environmental quality is noted.

Today, almost all issues related to world civil aviation are decided by the ICAO. This institution develops basic requirements for the operation of civil aviation, including requirements for certification according to the level of environmental impact. It also limits or bans the use of aircraft that do not meet environmental requirements. At the same time, the ICAO almost does not deal with issues of compensation for environmental damage from the impact of aircraft on the environment. These issues are left to be decided by each individual state.

Theoretical and methodological approaches to ecological and economic assessment of the impact of civil aviation on the environment are almost completely absent. Theoretical and methodological provisions related to the creation of a mechanism for compensation of ecological and economic losses from air transport processes require further deepening and addition.

An increase in the volume of air transport on the territory of our country will naturally lead to a corresponding increase in the negative impact on the environment. So, even if now the quantitative indicators of ecological and economic losses are not as significant as they may be, in the near future their significant growth is possible.

4. LABOR PROTECTION

4.1 Introduction

Labor protection is a system composed of sanitary-hygienic, legal, sociological, technical, organizational, and medical means. The main goal of labor protection system is to preserve the health and working capacity of a worker in the workplace.

In order to perform the effective management of machines and mechanisms, and recommend optimal and safe working conditions, the labor protection turns to ergonomics - a discipline that studies the relationship between a person and the working environment. Another discipline, that helps to solve the tasks of labor protection, is an engineering psychology. It studies the psychological features of a person's labor activity, taking into account the scientific organization of work and the aspects of safety psychology.

4.2. Analysis of working conditions in the workplace

One of the advantages of the operation and repair of aviation equipment is that a number of technological processes are general processes for the specified technologies, such as cargo operations, operation of pressure vessels, washing and painting of parts, welding operations, operation of electrical installations, etc. So the classification of dangerous and harmful production factors during the operation of the aircraft can as well be used for aircraft repair process. Such factors are:

1. Planes, special vehicles and self-propelled mechanisms that move (section 43 of the Occupational Health and Safety Act, 1993 (Act No. 85 of 1993)).

2. Products, blanks and materials that move (section 43 of the Occupational Health and Safety Act, 1993 (Act No. 85 of 1993)).

3. Increased level of static electricity (Labor protection instruction for working with batteries n.1499)

4. Increased level of laser radiation in the working area (Directive 2006/25/EC - artificial optical radiation).

5. Location of the workplace at a considerable height relative to the ground surface (The Work at Height Regulations 2005).

6. Absence or lack of natural lighting (Lighting legislation BS EN 50172).

7. Increased level of noise, vibration, ultra- and infrasound (SSN 3.3.6.037-99 Sanitary norms of occupational noise, ultrasound and infrasound).

8. Increased brightness of light (Lighting legislation BS EN 50172).

9. Increased light flux pulsation (Control of Electromagnetic Fields at Work Regulations 2016, n.588).

10. Increased level of ultraviolet and infrared radiation (The Control of Artificial Optical Radiation at Work Regulations 2010).

11. Chemical substances (toxic, irritating, sensitizing, carcinogenic, mutagenic, those affecting reproductive function) that may be used in an aircraft parts (Standard instruction on labor protection for workers performing loading and unloading and warehouse work with flammable, explosive and dangerous goods (31791)).

12. Fuel and lubricant materials, special fluids and toxic chemicals that may enter the human body through the respiratory system, gastrointestinal tract, skin and mucous membranes (Standard instruction on labor protection for workers performing loading and unloading and warehouse work with flammable, explosive and dangerous goods (31791), Instruction on labor protection during work with the use of fire-hazardous materials and harmful substances (31921)).

13. Pathogenic microorganisms and products of their vital activity (Standard instructions for the sanitary maintenance of premises and equipment of production workshops and territory n. 31815).

14. Physical (static and dynamic) and neuropsychological overloads (emotional, analyzer overstrain) (Standard instruction on labor protection for workers performing loading and unloading and warehouse work (31794)).

The basic technological processes of operation and repair of aviation equipment may subject the workers to danger, so it is important to consider the labor safety during the performance of all these factors. The following main tasks, directed at maintaining labor safety, can be formulated:

1. Training on labor protection issues.

Training is a very important stage in the prevention of industrial injuries - a component of the occupational health and safety management system. It is carried out in accordance with the Standard Regulation, and is also aimed at the implementation in Ukraine of a system of continuous training on occupational safety issues for employees in the process of work, pupils, and students of educational institutions.

2. Expertise.

Expertise is a type of scientific and practical activity of specially authorized state bodies, expert formations, citizens' associations, that is aimed at preparing an expert opinion on the compliance of the object, planned or existing economic and other activities with the norms and requirements of legislation on labor protection.

3. Attestation of workplaces according to working conditions, certification of objects.

The main purpose of the certification is to regulate the relationship between the owner and the employee regarding the realization of the rights to health and safe working conditions, benefits and compensations for working in unfavorable conditions, and pension payments. Certification is mandatory for all enterprises where there are harmful and dangerous production factors.

Attestation of workplaces involves:

- identification of the causes of formation of harmful and dangerous production factors;
- a comprehensive assessment of the factors of the production environment and the labor process for their compliance with the legislation on labor protection;
- substantiation of assigning the workplace to the appropriate category with harmful working conditions;
- establishment (confirmation) of employees' right to preferential pension provision and other benefits and compensations;
- development of a set of measures aimed at improving working conditions and improving the health of employees.

4. Regulation of the labor process.

The work schedules, days off, vacations and breaks in a company are firstly established by labor protection legislation, and only then - by the rules of internal labor regulations (in this case, of aircraft company). The internal company rules should not be in opposition to labor protection legislation. The labor process is also regulated by many regulatory acts, which extend to the airline industry. Naturally, the more harmful and dangerous factors are present in technological processes at the enterprise, the more regulatory restrictions are applied to the labor process.

5. Ensuring the safety of equipment, technological processes, buildings and territories.

The conducting of the diagnostics of equipment, examination of the state of existing buildings, structures, machines and mechanisms, technical inspections and technical restrictions during operation of boilers, pressure vessels, lifting, electrical and other equipment must be made only by the expert and technical centers of the State Labor Inspection and Protection.

6. Ensuring of sanitary and hygienic working conditions, sanitary and household, treatment, preventive and medical care.

This task involves:

- creation of psychologically optimal modes of work and rest;
- organization and functioning of sanitary and industrial laboratories;
- implementation of measures related to easing and improvement of working conditions;
- fulfillment of requirements:
- hygienic regulation of dangerous factors of a physical, chemical, and biological nature present in production;
- limit load norms for women, minors;
- restrictions on the employment of women and minors in heavy jobs and jobs with harmful and dangerous working conditions;
- eligibility for night overtime work and work on weekends for employees of certain categories;

- regulation of the work of certain categories of workers in areas with special natural conditions and conditions of increased health risk;
- labor protection of the disabled.

7. Warning about the occurrence of dangerous situations.

The occurrence of a dangerous situation may be related to the production environment or the internal state of the employee and lead to an accident. Underestimating the danger is one of the most common psychological causes of accidents. So the employees must be properly instructed to understand the key safety principles of their work.

In production, warnings about the presence of places with high potential danger, transmission of messages about specific accidents, information leaflets issued in connection with this are effective.

An important role is played by warning posters, which are a means of attracting attention, correct understanding or the appearance of a desired emotional reaction. Posters can be positive, reminding the direction of the right actions, or negative (intimidating), which show the consequences of wrong actions, sometimes in exaggeration, for better psychological effect.

8. Ensuring labor and production discipline.

It is known that, not only economic factors depend on the observance of labor and production (technological) discipline at the enterprise, but also the probability of accidents, occupational diseases, emergency situations.

Unfortunately, managers do not always remember this and therefore do not pay necessary attention to the health and safety.

According to modern psychological research, there is a lot of evidence that the state of labor discipline primarily depends on the obligation to comply with labor protection requirements, which guarantee a high level of labor safety. And the level of production (technological) discipline, in addition, is directly related to the possibility of emergency situations. At the same time, it is very well known that very few workers follow the rules, even about their safety, if the control system is ineffective or completely absent. The workers may even not be aware that they do something wrong. In this case, errors in the actions of employees that can lead to injuries are most likely to happen.

4.3. Analysis of working conditions and development of protective measures

The most connected factors to the theme of my diploma are:

1. Electricity.

Electrical safety is a system of organizational and technical means that protect people from harmful and dangerous effects of electric current, electric arc, electromagnetic field and static electricity.

The effect of electric current on the human body.

A person is surrounded by electrical installations both at work and in everyday life, like laptops, phones, kitchen appliances such as microwave etc. These are devices in which electrical energy is produced, transformed, transmitted, distributed and consumed. Electrical installations mean a set of machines, devices, lines and auxiliary equipment (together with buildings and premises in which they are installed) that have a function of the production, conversion, transformation, transmission of electrical energy and its transformation into another type of energy.

The electric current cannot be safely detected by human senses, so it is very dangerous. The action of current is very dangerous because when a person touches conductive parts, the current flows throughout the human body, disrupting the work of the vital organs. It can cause serious injury or death. Electric injury should be understood as an injury caused by the action of an electric current or an electric arc.

To ensure the electrical safety, the following technical methods or their combination must be used: low voltage, protective grounding, zeroing, equalization of potentials, electrical separation of networks, protective disconnection, isolation of conductive parts (working, additional, reinforced, double), compensation of earth fault currents , fencing devices, warning alarms, interlocks, safety signs, protective devices and safety devices.

The use of low voltages is an effective measure that reduces the danger of servicing electrical installations in rooms with special and increased danger. Dry galvanic cells, batteries, rectifiers, and step-down transformers are used as sources of low voltages.

When working under voltage, be sure to use a tool with handles made from insulated material, such as rubber, as well as means of personal protection (dielectric gloves, boots), standing on a dielectric mat. Electrical injuries often occur as a result of reduced attention, and loss of orientation during maintenance and repair of electrical installations. In such cases, effective measures are taken to eliminate accidental contact with current-carrying parts of electrical installations due to their reliable isolation, the use of protective casings and fences, the laying of wires and cables in hard-to-reach places at an inaccessible height, in pipes or boxes, under floors, panels, in walls (hidden wiring) etc.

Locking devices are effective means of protection against accidental contact with current-carrying parts. Structurally, they are electrical and mechanical. The principle of operation of electrical blocking is that when opening cabinet doors or removing protective covers of electrical installations, the electrical circuit of the power supply of the electrical installation or other electrical equipment is automatically broken. The mechanical lock prevents the door from opening if the electrical installation is not de-energized (the switch or other starting device is turned off).

If the procedures are performed with critical errors, the warning system will be activated. Warning light or sound signaling informs the worker of danger and allows to take precautionary measures in a timely manner during inspections and repairs of electrical and radio-electronic equipment. On the special equipment of the aircraft, signaling is very widely used and is an effective tool that warns of incorrect actions of the engineering and flight crew.

2. Lighting.

One of the factors that determine good working conditions is rational lighting of the working area and workspace. The bad or incorrectly designed lighting can greatly increase tiredness of a worker and can lead to accidents. If the lighting of the production premises is correctly calculated and executed, the worker's eyes for a long time will retain the ability to distinguish objects and work tools well, without getting tired. This contributes to the reduction of occupational injuries and occupational eye diseases.

In aviation, during operational maintenance at night, unsatisfactory or insufficient lighting of the maintenance area can lead to a reduction in the quality of the work performed.

For example, cracks, abrasions that have appeared, fuel and lubricant leaks, mechanical impurities and water in the fuel may remain unnoticed, which, in turn, leads to a decrease in flight safety. Poor lighting of the apron, aircraft parking lot, and taxiways with an increase in the number of aircraft and mechanized vehicles moving at high speed can cause many cases of injuries.

Insufficient lighting of workplaces is one of the reasons for low productivity. In this case, the worker's eyes are very strained, it is difficult to distinguish between processed objects, the pace and quality of work decreases, and the general condition deteriorates.

The eyes are negatively affected by both insufficient and excessive lighting. Excessive illumination leads to blindness, which is characterized by a sharp irritating effect and tearing in the eyes, while the worker's eyes tire quickly and visual perception deteriorates.

Lighting of industrial premises and workplaces is characterized by light flux, light power, illumination, and brightness.

The lighting must satisfy a number of requirements: be sufficient so that the eyes can distinguish details without strain; constant in time, for this the voltage in the power supply network should not fluctuate by more than 4%; evenly distributed over work surfaces, so that the eyes do not have to feel a sharp light contrast; not to cause a blinding effect on the human visual organs of both the light source itself and the reflective surfaces in the worker's field of vision (reducing the brightness of light sources is achieved by using lamps that scatter light); not to cause sharp shadows at workplaces, passageways, passages in case of correct location of lamps (spotlights); storms are safe - do not cause an explosion, fire in the premises.)

3. Electromagnetic fields

At workplaces, the intensity of the electromagnetic field depends on the power of the radiation source and its distance to the workplace.

Electromagnetic fields (EMF) act on human body depending on the intensity of the field, its nature, frequency range and duration of exposure (irradiation).

Functional disorders caused by the action of EMF are reversible after the termination of irradiation. At the same time, it should be taken into account that the reversibility of functional shifts is not unlimited. It is determined by the intensity of irradiation, duration of action, as well as individual characteristics of the body. Therefore, the prevention of occupational diseases should include organizational measures along with the development of technical means of protection.

It is necessary to prevent occupational diseases, so the allowable sanitary norms of exposure at workplaces must be established, preliminary and periodic medical examinations of persons that are subjected to EMF in their work (for example, EMF radio frequency generator) must be performed.

The limit density of the EMF energy flow of radio frequencies 300 MHz...300 GHz at workplaces and in places where personnel associated with the action of EMFs may be located is established based on the permissible value of the energy load on the body and the time spent in the radiation zone. The dose of X-ray radiation to personnel should not exceed the values established by radiation safety standards.

4.4. Fire Safety Rules at the workspace

Ensuring fire safety is an integral part of the state activity regarding the protection of life and health of people, national wealth and the environment. The Law of Ukraine "On Fire Safety" defines the general legal, economic and social foundations of ensuring fire safety on the territory of Ukraine, regulates the relations of state bodies, legal entities and individuals in this field, regardless of their type of activity and forms of ownership.

Fire and explosion safety requirements generally consist of requirements for fire prevention and fire protection systems, as well as for explosion prevention and explosion protection [5].

To meet the requirements for the fire prevention system, it is necessary to ensure the maximum possible use of non-combustible, hard-to-burn and combustible substances and materials, limit the mass and/or volume of such substances, materials and develop the safest way of their placement. It is also necessary to insulate the combustible medium, maintain the concentration of combustible gases, steam, suspensions and/or oxidizer in the mixture low enough so the combustion is not possible; sufficient concentration of the phlegmatizer (its component part) in the air of the object must be protected. The temperature and pressure must be maintained at such values at which flame propagation is impossible. The maximum mechanization and automation of technological processes related to the conversion of combustible substances can help to reduce casualties and comply with fire and explosion safety requirements too. The fire-hazardous equipment, if possible, must be installed in isolated rooms or on open areas. Use of sealed equipment and containers for combustible substances, use of devices to protect production equipment with these substances from damage and accidents should also be made. Installation of disconnecting, disconnecting and other devices; use of isolated compartments, chambers, cabins, etc can help to meet the safety standards as well.

The requirements for the fire protection system are satisfied by the use of: means of fire detection, fire extinguishing and appropriate fire equipment; automatic fire alarm and fire extinguishing systems; main building structures of objects with regulated limits of fire resistance and fire spread; saturating the structures of objects with fire retardants and applying flame retardant paints (compounds) to their surface; equipment that ensures the limitation of the spread of fire; organization of timely evacuation of people; means of collective and individual protection of people from dangerous factors of fires; smoke protection systems.

In general, organizational measures to create fire safety include: organization of fire protection (preventive and operational maintenance of the object), informing the workers, employees and the public of fire safety rules, instructions on the procedure for working with fire-hazardous substances and materials, compliance with the fire prevention regime and actions people should take in the event of a fire, production and use of means of visual agitation.

Conclusion to the Labor Protection Part

The main goal of improving working conditions is to achieve a social effect, i.e. ensuring labor safety, preserving the life and health of workers, reducing the number of accidents and diseases at work. Improving working conditions also yields economic results: an increase in profits (due to an increase in labor productivity); reduction of costs associated with compensation for work with harmful and difficult working conditions; reduction of losses associated with injuries, occupational morbidity; decrease in staff turnover, etc.

GENERAL CONCLUSIONS

In this diploma work were created:

- preliminary design of the long-range passenger aircraft with 440 seats capacity;
- the schematic design of the layout of the long-range aircraft with 440 passengers;
- the center of gravity of the airplane calculations;
- the calculation of the main geometrical parameters of the passenger equipment element;
- the design of a new fuselage concept.

The created aircraft meets the intended purpose of use, its geometric characteristics will provide the necessary aerodynamic characteristics, which will lead to efficient use.

A new fuselage design is proposed. It has better characteristics and will be more enduring.

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Appendix

Appendix A

INITIAL DATA AND SELECTED PARAMETERS

Passenger Number Flight	440
Crew Number	2
Flight Attendant or Load Master Number	11
Mass of Operational Items	5633.42 kg
Payload Mass	
Cruising Speed	905 km/h
Cruising Mach Number	0.8499
Design Altitude	13 km
Flight Range with Maximum Payload	9700 km
Runway Length for the Base Aerodrome	3.3 km
Engine Number	2
Thrust-to-weight Ratio in N/kg	2.8
Pressure Ratio	35
Assumed Bypass Ratio	5
Optimal Bypass Ratio	3.5
Fuel-to-weight Ratio	0.38
Aspect Ratio	8.7
Taper Ratio	3
Mean Thickness Ratio	0.11
Wing Sweepback at Quarter Chord	35 degree
High-lift Device Coefficient	1.1
Relative Area of Wing Extensions	0

Wing Airfoil Type - supercritical
Winglets - yes
Spoilers - yes

Fuselage Diameter	6.2 m
Finesse Ratio	11.9
Horizontal Tail Sweep Angle	40 degree
Vertical Tail Sweep Angle	46 degree

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point	0.48068
Induce Drag Coefficient	0.00886

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

Cruising Mach Number	0.84988
Wave Drag Mach Number	0.85729
Calculated Parameter D_m	0.00742

Wing Loading in kPa (for Gross Wing Area):

At Takeoff	4.977
At Middle of Cruising Flight	4.035
At the Beginning of Cruising Flight	4.772

Drag Coefficient of the Fuselage and Nacelles	0.00659
Drag Coefficient of the Wing and Tail Unit	0.00888

Drag Coefficient of the Airplane:

At the Beginning of Cruising Flight	0.02652
At Middle of Cruising Flight	0.02490
Mean Lift Coefficient for the Ceiling Flight	0.48068
Mean Lift-to-drag Ratio	19.30092
Landing Lift Coefficient	1.469
Landing Lift Coefficient (at Stall Speed)	2.203
Takeoff Lift Coefficient (at Stall Speed)	1.807
Lift-off Lift Coefficient	1.319
Thrust-to-weight Ratio at the Beginning of Cruising Flight	0.467
Start Thrust-to-weight Ratio for Cruising Flight	2.510
Start Thrust-to-weight Ratio for Safe Takeoff	2.537
Design Thrust-to-weight Ratio	2.638
Ratio $D_r = R_{cruise} / R_{takeoff}$	0.989

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

Takeoff	35.8856
Cruising Flight	58.6593
Mean cruising for Given Range	61.3972

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.02863
Block Fuel	0.32383

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.12764
Horizontal Tail	0.01152
Vertical Tail	0.01198
Landing Gear	0.03589
Power Plant	0.08192
Fuselage	0.08750
Equipment and Flight Control	0.10468
Additional Equipment	0.00805
Operational Items	0.01947
Fuel	0.35246
Payload	0.15893

Airplane Takeoff Weight	289310 kg
Takeoff Thrust Required of the Engine	381.61 kN

Air Conditioning and Anti-icing Equipment Weight Fraction	0.0195
Passenger Equipment Weight Fraction (or Cargo Cabin Equipment)	0.0122
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.0064
Furnishing Equipment Weight Fraction	0.0162
Flight Control Weight Fraction	0.0040
Hydraulic System Weight Fraction	0.0127
Electrical Equipment Weight Fraction	0.0225

Radar Weight Fraction	0.0019
Navigation Equipment Weight Fraction	0.0029
Radio Communication Equipment Weight Fraction	0.0015
Instrument Equipment Weight Fraction	0.0034
Fuel System Weight Fraction	0.0116

Additional Equipment:

Equipment for Container Loading	0.0061
No typical Equipment Weight Fraction (Build-in Test Equipment for Fault Diagnosis, Additional Equipment of Passenger Cabin)	0.0020

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed	279.58 km/h
Acceleration during Takeoff Run	1.89 m/s^2
Airplane Takeoff Run Distance	1588 m
Airborne Takeoff Distance	578 m
Takeoff Distance	2166 m

CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed	256.6 km/h
Mean Acceleration for Continued Takeoff on Wet Runway	0.07 m/s^2
Takeoff Run Distance for Continued Takeoff on Wet Runway	5611 m
Continued Takeoff Distance	6189.38 m
Runway Length Required for Rejected Takeoff	6418.44 m

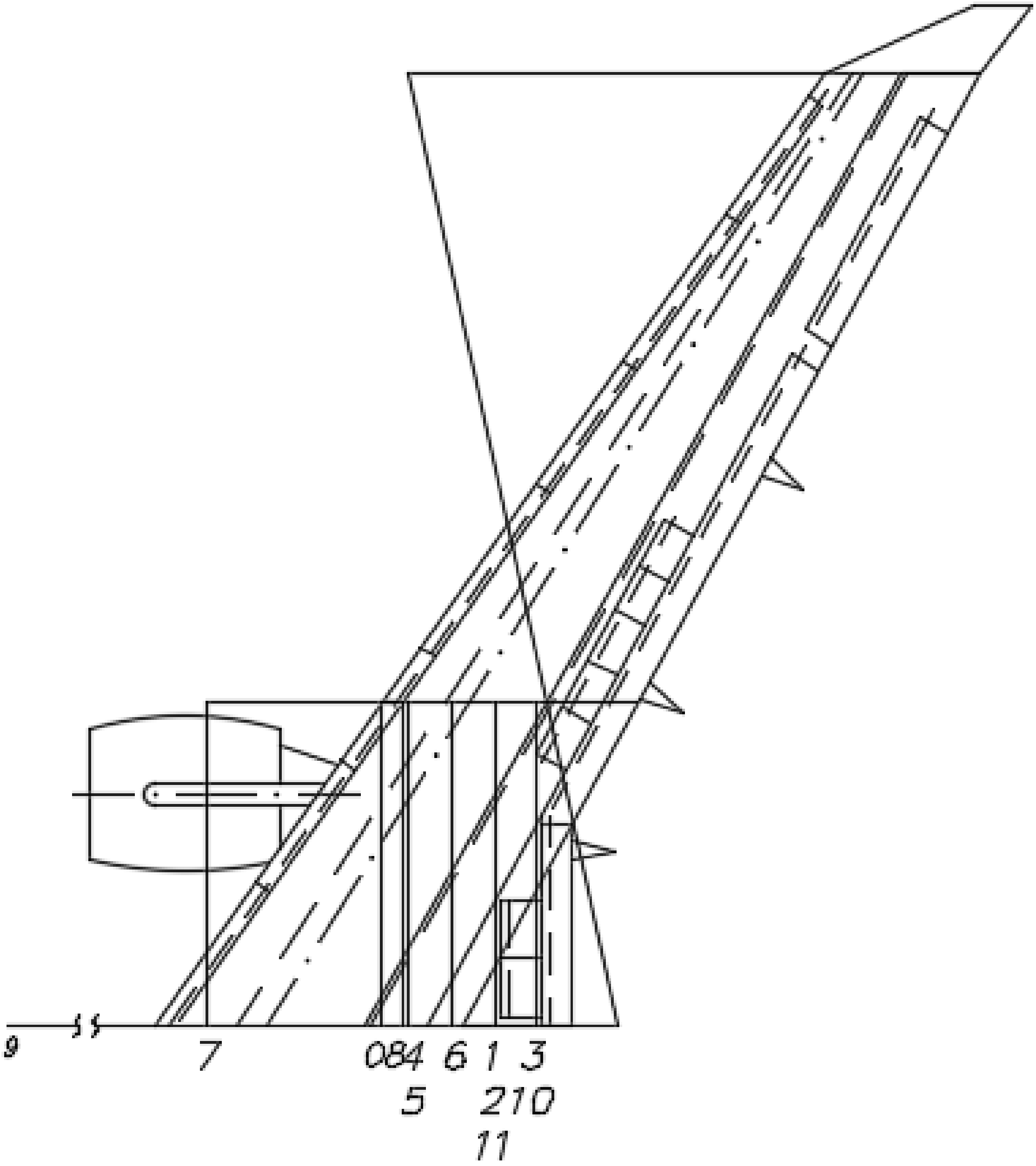
LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight	210219 kg
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight	24.1 min.
Descent Distance	60.52 km
Approach Speed	242.86 km/h
Mean Vertical Speed	1.97 m/s
Airborne Landing Distance	514 m
Landing Speed	227.86 km/h
Landing run distance	713 m
Landing Distance	1227 m
Runway Length Required for Regular Aerodrome	2049 m
Runway Length Required for Alternate Aerodrome	1742 m

Appendix B

N	Object name	C.G coordinates Xi, м
1	Wing (structure)	3,528
2	Fuel system	3,528
3	Airplane control, 30%	4,704
4	Electrical equipment, 30%	0,784
5	Anti-ice system , 50%	0,784
6	Hydraulic systems , 70%	2,166
7	Power plant	-5,44
8	Equipped wing without landing gear and fuel	0,617
9	Nose landing gear	-23,066
10	Main landing gear	4,704
11	Fuel	3,528

Appendix B



Appendix C

N	Object name	C.G coordinates Xi, м
1	Fuselage	34,72
2	Horizontal tail	60,29
3	Vertical tail	60,29
4	Radar	0,5
5	Radio equipment	1
6	Instrument panel	2,5
7	Aero navigation equipment	2
8	Lavatory 1, galley 1, lavatory 2, galley 2 20%	5,014
9	Lavatory 3, galley 3, lavatory 4, galley 4, lavatory 5, galley 5 30%	20,42
10	Lavatory 6, lavatory 7, lavatory 8, lavatory 9 20%	25,786
11	Lavatory 10, galley 6, lavatory 11, galley 7, galley 8, galley 9 30%	54,728
12	Aircraft control system 70%	34,72
13	Hydro-pneumatic sys 30%	48,608
14	Electrical equipment 70%	34,72
15	Not typical equipment	20
16	Furnishing and thermal equipment	34,72
17	Anti ice and air-conditioning system	34,72
18	On board meal	25
19	Passenger seats (economic class)	34
20	Seats of flight attendance	22
21	Seats of pilot	3,3
22	Additional equipment	18
23	Equipped fuselage without payload	34,325
24	Baggage	25
25	Cargo, mail	25
26	Crew/attendant	20
27	Passengers(economy)	34
28	Monitors	34

Appendix C