МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Кафедра конструкції літальних апаратів

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
д-р техн. наук, проф.
_____________ С. Р. Ігнатович
«_____» ___________ 2020 р.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)
ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ

"БАКАЛАВР"

Тема: «Аванпроект дальномагістрального літака високої пасажиромісткості»

Виконала: ___________ **А.В. Довбня**

Керівник: канд.техн.наук, доцент ___________ **Т.П. Маслак**

Нормоконтролер: канд.техн.наук, доцент ___________ **С.В. Хижняк**

Київ 2020

MINISRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

Department of Aircraft Design

AGREED
Head of the Department
Professor, Dr. of Sc.
_________S.R. Ignatovych
«___» _______ 2020 y.

DIPLOMA WORK

(EXPLANATORY NOTE)
OF ACADEMIC DEGREE
«BACHELOR»

Theme: «Preliminary design of a high seating capacity long range aircraft»

Performed by: __________ **A.V. Dovbnia**

Supervisor: PhD, associate professor __________ **T.P. Maslak**

Standard controller: PhD, associate professor __________ **S.V. Khizhnyak**

Kyiv 2020

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty

Department of Aircraft Design

Academic Degree «Bachelor»

Speciality: 134 "Aviation and Rocket-Space Engineering"

APPROVED
Head of the Department
Professor, Dr. of Sc.
_________S.R. Ignatovych
«___» _______ 2020 year

TASK

for bachelor diploma work

DOVBNIA ANASTASIIA

1. Theme: «**Preliminary design of a high seating capacity long range aircraft**»

confirmed by Rector's order from 05.06.2020 year № 801/ст

2. Period of work execution: from 25.05.2020 year to 21.06.2020 year.

3. Work initial data: cruise speed V_{cr}=905 km/h, flight range L=11000 km, operating altitude H_{op}=12 km, 460 passenger.

4. Explanation note argument (list of topics to be developed): choice and substantiations of the airplane scheme, choice of initial data; engine selection, aircraft layout, center of gravity position calculation, designing of pilot's seat.

5. List of the graphical materials: general view of the airplane (A1×1); layout of the airplane (A1×1); pilot seat assembly drawing (A1×1)

Graphical materials are performed in AutoCad, CATIA.

6. Calendar Plan

Task	Execution period	Signature
Task receiving, processing of statistical data	25.05.2020–28.05.2020	
Aircraft geometry calculation	29.05.2020–30.05.2020	
Aircraft layout	29.05.2020–31.05.2020	
Aircraft centering	31.05.2020–04.06.2020	
Graphical design of the parts	02.06.2020–10.06.2020	
Preliminary defence	10.06.2020–10.06.2020	
Completion of the explanation note	11.06.2020–15.06.2020	

7. Task issuance date: 25.05.2020 year

Supervisor of diploma work ____________ T.P. Maslak

Task for execution is given for ____________ A.V. Dovbnia

ABSTRACT

Explanatory note to the diploma work «Preliminary design of a high seating capacity long range aircraft» contains:

pages, figures, tables, references and 4 drawings

Object of the design is a long range aircraft with a high passenger capacity.

Subject of the design – the conceptual design of the pilot seat assembly with stress-strain analysis of the seat rail system.

Aim of the diploma work is the preliminary design of the long range passenger aircraft based on the prototypes, layout of the passenger cabin and conceptual design of the pilot seat.

The method of design is analysis of the prototypes and selections of the most advanced technical decisions, the geometrical characteristics estimation, centre of gravity calculations of the designing aircraft, stress-strain analysis of the rail seat system,

Practical implementation of the results is defined by the designing of the long range aircraft with a high passenger capacity, calculations and drawings of the aircraft layout and conceptual design of the pilot's seat.

The materials of the diploma could be recommended for the students of aviation specialties, for the aircraft operational companies, etc.

AIRCRAFT, PRELIMININARY DESIGN, LAYOUT, CENTER OF GRAVITY POSITION, PILOT SEAT, RAIL SYSTEM

Introduction

The aircraft that now make up the jet fleet are of three types: narrowbody short and medium range planes with passenger capacity up to 150 (75% of the world fleet). The next type is narrow-body medium and long range aircraft (7% of the fleet) with passenger capacity up to 180 passengers.

The most efficient and heavily traveled type of the aircraft is a medium and long range wide-body airraft, which make up about 18% of the fleet. Furthermore they are efficient even on the short distance for high density routes. So, the aim of my diploma work is to increase the spectrum of wide-body medium and long range aircraft (or replace the narrowbody jets of 13 or 20 years old on long range) by the new one with more fuel efficiency and more technological, and less noisy.

Considering aircraft's type allows transporting a great number of passengers and cargo at a distance more than 7000 km without refueling. It helps transporter to save money and time.

After analyzing of the selected segment on the market, I chose Boeing 777-300, Boeing 777-300ER and Airbus A350-1000 as prototypes for the designed aircraft. Selected prototypes have similar characteristics.

The aim of this work is to develop a long-range aircraft with high passenger capacity. It should be the most profitable from an economic point of view, both for the manufacturer and for the transporter. For this, in the main part of the work, I use the most appropriate technical characteristics of each of the prototypes. Also, in a special part, I will also consider the design of the pilot seat for perfect ergonomic conditions, since pilot comfort is very important for the safety of long-range aircraft.

Content

1. Preliminary design of a high seating capacity long range aircraft

1.1 Prototypes analysis and description of designing aircraft

In order to form an idea of aircraft design, first of all, we must choose the optimal design parameters. It is necessary to take into account certain technical characteristics, such as flight-technical, geometrical, economic as well as weight and aerodynamic. There are several stages in the formation of the general view of the aircraft. At the first, the statistical method is widely used, the above parameters are compared. The second stage includes a full aerodynamic calculation of all aircraft units. The prototype for my work will be long range aircraft with high seating capacity. To my mind, in this case the best examples of long range aircraft are Boeing 777-300, Boeing 777-300ER and Airbus A350-1000. The statistic and technical data of the prototype aircraft are presented in Table 1.1.

Table 1.1 – Statistic data of prototypes

Name and dimensions	Boeing 777-300	Boeing 777-300ER	Airbus A350-1000
Number of passenger	450	479	412
Crew, numbers	2	2	2
Range of flight with $m_{k\ max}$, km	11000	14600	15600
Cruising speed, Vkm/h	905	905	903
Wing span	60.9	64.8	64.8
Number and type of engines	2×R-R Trent 892	2×General Electic GE90-115B	2 ×R-R Trent XWB
Maximum flight altitude km	13.1	13.1	13.15
Cruising thrust, kN	440	513	411
Maximum take off weight t	299.4	351.8	308

All three prototypes have approximately the same characteristics. For my work is necessary to choose the best parameters.

The aerodynamic scheme of designed aircraft is a cantilever low-wing plane. The design of fuselage is semi-monocoque and has circular cross section. There are two parts of double-hinged rudder structure. One of the part (upper) is controled by boosters of control system, and the other (lower) controlled by the pedal. For aircraft is important weight balancing and aerodynamic. Rudders meet these parameters. Rudder is equipped by trim and servo tabs. Landing gear will extend mechanically, if hydrosystem of landing gear doesn’t work.

Designing aircraft has a widebody fuselage with length in 73.9 m. It’s semimoqoque type. Fuselage provides space for passangers, cargo, crew, etc. It’s consists of nose, main and tail part. Also wing is attached to the fuselage.

Wing is one of the important part of any aircraft. It produces lift force, provides aircraft stability and spaces fuel. In our case we have low-wing type of aircraft with sweepback wing high aspect ratio. This type of construction is widely used by Boeing-family aircraft. It’s good for landing gear retraction and extension, and more comfortable for maintenance. The task of tail unit is to stabilize aircraft in flight. It consists of vertical and horizontal stabilizers, rudder and elevator.

1.2 Aircraft geometry calculations and fuselage layout

Aircraft’s layout consists of the composing the relative disposition of main units, construction elements, number of passengers etc.

We need to select such parameters and the scheme of the aircraft which have best satisfying operational requirements.

1.2.1 Wing geometry calculation

During the preliminary design of the aircraft, we will find the geometrical parameters of the main parts of the aircraft. The first iteration will include the statistaic data of prototypes and of course the statistis coefficient for the biggest part of the aircraft. The initial data for the calculation were received by the computer program at the department and presented in the Appendix A.

Wing loading explaine the ratio of the takeoff weight of the aircraft to the area of the wing. From the Appendix A we have maximum take off weight m_0 and specific wing load P_0 of our designing plane, so the wing area is:

$$S_w = \frac{m_0 \cdot g}{P_0} = \frac{335686 \cdot 9,8}{5298} = 520.937\ (m^2)$$

The received value of the area is too big, if we compare it with the area of the wing of prototypes. Based on the experience of the real design beraou we tale the area equal to 427,8 (m2).

After the area of the wing, we could find wing span through the aspect ratio equal to 8,7:

$$l = \sqrt{S \cdot \lambda} = \sqrt{427.8 \cdot 8.7} = 61(m)$$

The root chord of the wing could be found from the next equation:

$$b_o = \frac{2S_w \cdot \eta_w}{(1 + \eta_w) \cdot l} = \frac{2 \cdot 427.8 \cdot 3,3}{(1 + 3,3) \cdot 61} = 10.76(m)$$

The tip chord is:

$$b_t = \frac{b_o}{\eta_w} = \frac{10.76}{3,3} = 3.26(m)$$

Board chord is:

$$b_{ob} = b_0 \cdot (1 - \frac{(\eta_w - 1) \cdot D_f}{\eta_w \cdot l_w}) = 9.996(m)$$

The type of the wing construction is semi-monocogue, with two spars. According to the recomandations the position of the spars from the leading edge of the wing are located:

$$\bar{x}_i = \frac{x_i}{b},$$

where x_i – distance of i-spars to the leading edge of the wing in current cross-section, b – chord of the wing in the current cross section.

Wing with two spars: $\overline{X}_1 = 0{,}2$; $\overline{X}_2 = 0{,}6$.

The distance between two spars determines the width of the torsion box and the capacity of the fuel tanks.

The geometrical method of Mean Aerodynamic Chord (MAC) determination is shown on the figure 1.1.

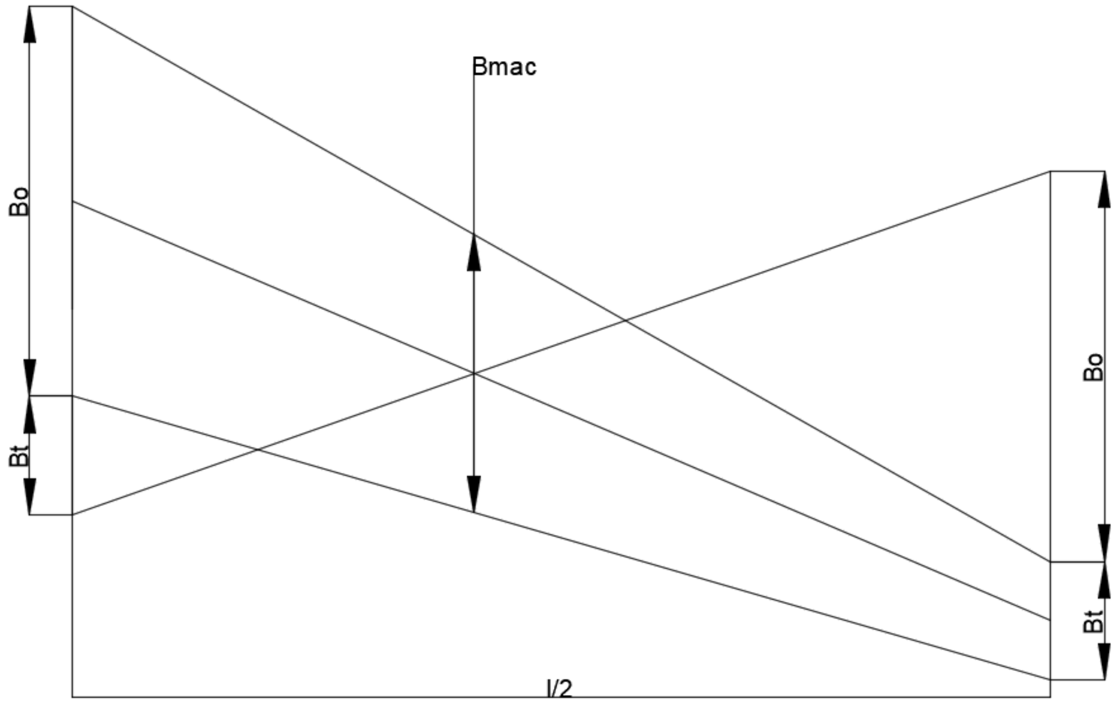

Figure 1.1 - Geometrical method of a mean aerodynamic chord determination

In our case we receive the length of the mean aerodynamic chord, which is equal b_{mac} = 7.692 m.

The full area of the wing is known, so we could find the geometry of high lift devices, and ailerons. According to the initial data we have double slotted flaps with rigid deflectors.

The geometric parameters of the ailerons span are:

$$l_{ail} = (0,3\ldots0,4)\cdot l/2 = 10.675\ m;$$

Ailerons chord is calculated from the recommendations based on statistic data, where b_i – is the current chord of a wing in a cross-section where we have ailerons:

$$b_{ail} = (0,22\ldots0,26)\cdot b_i;$$

Aileron's area could be found:

$$S_{ail} = (0,05\ldots0,08)\cdot S_w/2 = 12.834 m^2.$$

In the airplanes of the third generation including my prototype Boeing 777-300, there is a tendency to decrease relative span and ailerons area. So, we take the ailerons span equal to 10.675 m, because the wing’s span is equal 61m. In this case for the lateral control of the airplane we use spoilers together with ailerons.

The recommendation to the aerodynamic balance devices are:

$$Axial\ S_{axinail} \leq (0.25\ldots0.28)\ S_{ail} = 0,26 \cdot 12.834 = 3.34(m^2).$$

The range of aileron deflection are: upward $\delta'_{ail} \geq 25^\circ$; downward $\delta''_{ail} \geq 15^\circ$.

1.2.2 Fuselage layout

We need to take into account streamlining and cross section aerodynamic requirements during the chosing parameters of fuselage. The aircraft is not transonic, it’s mean the friction resistance and profile resistance is choosen from the statistic data. For subsonic airplanes fuselage nose part has to be:

$$l_{nfp} = 2{,}1 \cdot D_f = 2{,}1 \cdot 6.2 = 13(m),$$

where D_f – diameter of a fuselage.

When choosing a cross-sectional shape, it is necessary to take into account aerodynamic requirements, as well as requirements for strength and layout. The circular cross section is the most convenient, as it provides the smallest weight and maximum strength. Thus, we can get the smallest thickness of the fuselage skin.

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

Fuselage length is equal:

$$l_f = \lambda_f \cdot D_f = 11.9 \cdot 6.2 = 73.9(m);$$

$$l_{fnp} = \lambda_{fnp} \cdot D_f = 1.7 \cdot 6.2 = 10.5(\mathrm{m});$$

$$l_{frp} = \lambda_{frp} \cdot D_f = 1.77 \cdot 6.2 = 10.974(\mathrm{m}).$$

The fuselage mid-section first of all comes from the size of passenger cabin. One of the main parameter, determining the mid-section of passenger airplane is the height of the passenger cabin.

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

I choose the next parameters of the passenger cabin. Cabin height is equal:

$$H_{cab} = 1.48 + 0.17B_{cab} = 1.48 + 0.17 \cdot 5.84 = 2.473m$$

Windows are always places in one row. Its shape is rectangular with rounded corners. Since windows are stress concentrators, their shape and size are important for the strength of the fuselage. The window pitch corresponds to the bulkhead pitch and is 500 ... 510 mm.

For the economical cabin with a seating arrangement in the same row (3+3+3), the corresponding cabin width is determined

$$B_{cab}=n_{3block} \cdot b_{3block} + 2b_{aisle}+2\delta;$$

$$B= 3 \cdot 1650 +2 \cdot 500+2 \cdot 50=6050 \text{ mm}$$

For business class we take the accommodation of the seats in one row like 2+2+2 accomodation.

So, the width of business class cabin is:

$$B_{cab}=n_{2block} \cdot b_{3block} + 2b_{aisle}+2\delta= 3 \cdot 1200 +2 \cdot 600+2 \cdot 250=5300 \text{ mm}.$$

The length of passanger cabin is equal:

$$L_{cab}= l_1 + (n_{rows} – 1) \cdot L_{seatpitch} + L_2= 52.2m$$

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Compartment for cargo and mails are ussualy placed under the floor of passenger cabin. Cargo placement plays a very important role for the flight. Since the center of gravity of the fuselage depends on this. Incorrect placement of cargo, as well as passengers, can lead to emergency situations in flight, and even to disaster. The method of cargo placement can be calculated formally, in our case it is recommended to use the data of the prototype.

We will use unit of load on the floor K=400 ... 600 kg / m^2

The total mass of mail and commercial baggage which could be taken for the board are: mass of mail is 636 kg; mass of baggage is 7385 kg.

Cargo comprtment's area is defined:

$$S_{cargo} = \frac{m_c}{0{,}4 \cdot K} + \frac{m_l}{0{,}6 \cdot K} = 129.5\ (m^2);$$

Where, m_c and m_l - the mass of cargo mail and luggage.

Cargo compartment volume is equal:

$$V_c = \overline{V}_c \cdot n_{pas} = 0{,}23 \cdot 460 = 105.8 (m^3);$$

Luggage compartment design is similar to the prototype design.

1.2.3 Tail unit design parameters

The next task of the aerodynamic layout is a design of the tail unit, the geometrical arameters of a fin and horizontal tail, and the arms of tail unit. The area of the tail and the arms aprovide aerodynamic moments for the stability and control aircraft in longitudinal direction.

For the approximately calculations of the tail unit geometry we could take statistic data of aircrafts.

Vertical tail unit area is equal:

$$S_{vtu} = (0{,}12 \ldots 0{,}2) \cdot S_w;$$

Area of horizontal tail unit is equal:

$$S_{htu} = (0{,}18...0{,}25) \cdot S_w;$$

Much better could be calculated like:

$$S_{htu} = \frac{b_{mah} \cdot S}{L_{htu}} \cdot S_{htu} = \frac{10.32 \cdot 427.8}{18.5} \cdot 64.17 = 51.336\ m^2;$$

$$S_{vtu} = \frac{l \cdot S}{L_{vtu}} \cdot S_{vtu} = \frac{73.9 \cdot 427.8}{18.5} \cdot 64.17 = 77.004\ m^2;$$

Values L_{htu} and L_{vtu} depend on some factors. First of all: the length of the nose part and tail part of the fuselage, sweepback angle and wing location, and also from the conditions of stability and control of the airplane.

In the first approach we may take $L_{htu} \approx L_{vtu} = 18.5$m.

Determination of the elevator area:

$$S_{ea} = 0{,}345 \cdot S_{htu} = 0.345 \cdot 51.336 = 17.71\ (m^2)$$

Rudder area:

$$\mathrm{S_{rd}} = 0{,}4 \cdot \mathrm{S_{vtu}} = 0{,}4 \cdot 77.004 = 30.8(\mathrm{m}^2)$$

Elevator balance tabs area is equal:

$$\mathrm{S_{eb}} = (0{,}22...0{,}25) \cdot \mathrm{S_{ea}} = 0.23 \cdot 17.71 = 3.896(\mathrm{m}^2)$$

Rudder balance tab area is equal:

$$\mathrm{S_{rb}} = (0{,}2...0{,}22) \cdot \mathrm{S_{rd}} = 0.2 \cdot 30.8 = 6.78\ (\mathrm{m}^2)$$

The area of elevator trim tab:

$$S_{te} = 0,1 \cdot S_{elv} = 0,1 \cdot 17.1 = 1.71(m^2)$$

And for rudder of the aircraft with two engines:

$$S_{tr} = 0,05 \cdot S_{rud} = 0.05 \cdot 30.8 = 1.54(m^2)$$

The height of the vertical tail unit h_{bo} is determined:

$$l_{vtu} = 0,2 \cdot l_w = 0.2 \cdot 30.47 = 12.2 \text{ (m)}$$

Tapper ratio of horizontal and vertical tail unit we need to choose: η_{htu} = 2...3; η_{vtu} = 1…3.3. Tail unit aspect ratio we may recommend: λ_{vtu} = 0.8...1.5; λ_{htu} = 3.5...4.5. Determination of tail unit chords b_{end}, b_{MAC}, b_{root}:

Horizontal tail unit tip chord:

$$b_{tchtu} = \frac{2 \cdot S_{htu}}{(\eta_{htu}+1) \cdot l_{htu}} = \frac{2 \cdot 51.336}{(2+1) \cdot 18.5} = 1.59(m)$$

Vertical tail unit tip chord:

$$b_{tcvtu} = \frac{2 \cdot S_{vtu}}{(\eta_{vtu}+1) \cdot l_{vtu}} = \frac{2 \cdot 77.004}{(3+1) \cdot 12.2} = 2.1(m)$$

Horizontal and vertical tail unit root chord:

$$b_{rchtu} = b_{tchtu} \cdot \eta_{htu} = 1.59 \cdot 2 = 3.975(m)$$

$$b_{rcvtu} = b_{tcvtu} \cdot \eta_{vtu} = 2.1 \cdot 3 = 6.3(m)$$

Horizontal tail unit mean aerodynamic chord:

$$b_{MAChtu} = 0,66 \cdot \frac{\eta_{htu}{}^2+\eta_{htu}+1}{\eta_{htu}+1} \cdot b_{tchtu} = 0.66 \cdot \frac{2^2+2+1}{2+1} \cdot 1.59 = 1.84(m)$$

Vertical tail unit mean aerodynamic chord:

$$b_{MACvtu} = 0,66 \cdot \frac{\eta_{vtu}{}^2+\eta_{vtu}+1}{\eta_{vtu}+1} \cdot b_{tcvtu} = \frac{3^2+3+1}{3+1} \cdot 2.1 = 13.5(m)$$

Tail unit sweepback angle is not more than wing sweptback. We do it to provide the control of the airplane in shock stall on the wing. For the designing aircraft the sweepback angle of the horizontal tail is 35^0, for vertical tail is 40^0.

1.2.4 Landing gear desing

At the initial stage of design the only some parameters of landing gear is possible to find. The designied aircraft will be equipped with

Wheel base is the distance between main gear and nose gear. Main gear is is the closest to the aircraft center of gravity. During the landing operation, the main wheel touches first the ground. During the take-off operation, the main wheel leaves the ground last. On the other hand, main gear is carrying great portion of the aircraft load on the ground.

We have the displacement of the center of gravity of the aircraft and the axel of main wheels and nose wheels. Main wheel axel offset is:

$$e_g = 0,18 \cdot b_{MAC} = 0,18 \cdot 7.695 = 1.39(m)$$

Landing gear wheel base can be calculated by the equation:

$$B_g = (0,3\ldots0,4) \cdot l_f = 0.35 \cdot 73.9 = 29.56(m)$$

From the equation we can conclude, nose landing gear carries only 6...10% of aircraft weight. Nose wheel axial offset will be equal:

$$d_{ng} = B_g - e_g = 29.56 - 1.39 = 28.17\ (m).$$

Wheel track is:

$$K_{wt} = 0{,}42 \cdot B_g = 0{,}42 \cdot 29.56 = 12.42\ (m).$$

For forming conditions that can prevent the side nose-over the value K should be more then 2H, where *H* – is the distance from runway to the center of gravity.

According to the size and loading during take off we need to choose tyres for landing gear. It's important to consider dynamic loading also for the nose wheels, $K_g = 1.5...2.0$ – dynamics coefficient. The most practical to install breaks on the main wheel.

Nose wheel load is equal:

$$P_{nlg} = \frac{e_g \cdot m_0 \cdot g \cdot K_g}{B_g \cdot z_{nlg}} = \frac{1.39 \cdot 335686 \cdot 9.8 \cdot 1.6}{29.56 \cdot 2} = 123754.1\ (N)$$

Main wheel load is equal:

$$P_{mlg} = \frac{(B_g - e_g) \cdot m_0 \cdot g}{B_g \cdot z_{mlg} \cdot n_{mlg}} = \frac{(29.56 - 1.39) \cdot 335686 \cdot 9.81}{29.56 \cdot 12 \cdot 2} = 130759.6 (N)$$

Taking into account the maximum loads on the wheels and the speed of the aircraft during take off 305 km/h and during the landing 247 km/h, we choose the tires. Tires are high pressure types are installed on the prototype's landing gear (figure 1.2).

Figure 1.2 - Main landing gear of prototype Boeing 777-300

Taking into account the maximum loads on the wheels and the speed of the aircraft during take off (305 km/h) and during the landing (247 km/h), we choose the tires: 44 × 16 Type VII (DC-8-55 main gear tires) or 44.5 × 16.5 – 18 Type VII. Also the next type could be installed on the aircraft: 52×R22.36 PR.

1.2.5 Engine description

The power plant of a designed aircraft includes two Rolls-Roys Trent 892 engines and auxiliary power unit (APU). This is an axial flow, high bypass turbofan with three coaxial shafts. Rolls Royce 800 (figure 1.3) series has the next principle of operation: the fan is driven by a 5-stage low-pressure turbine, and the 8-stage and 6-stage compressors are driven by a single-stage turbine. This type of engine is characterized by an annular combustion chamber with 24 fuel injectors and is controlled by EEP. The compression ratio is 6.4:1 in cruise mode. The take off thrust of the engine depending on the aircraft varies from 340 to 413 kN. Fan has 26 diffusion bonded, wide chord titanium fan blades and its diameter is equal 280 cm.

The examples of application of Rolls Royce turbofan engine, bypass engine types you can see in a Table 2.2.

Table 2.2 - The examples of application of Rolls Royce Trent turbofan engine

Model	Thrust (kN)	Bypass ratio	Length (m)	Dry weight (kg)	Applications
Series 800	413	6.4:1	4.6	6078	Airbus 350 Boeing 777
Series 700	315	5:1	5.6	6160	Airbus 330
Series 900	374	8.6	5.5	6246	Airbus 380 Boeing 747

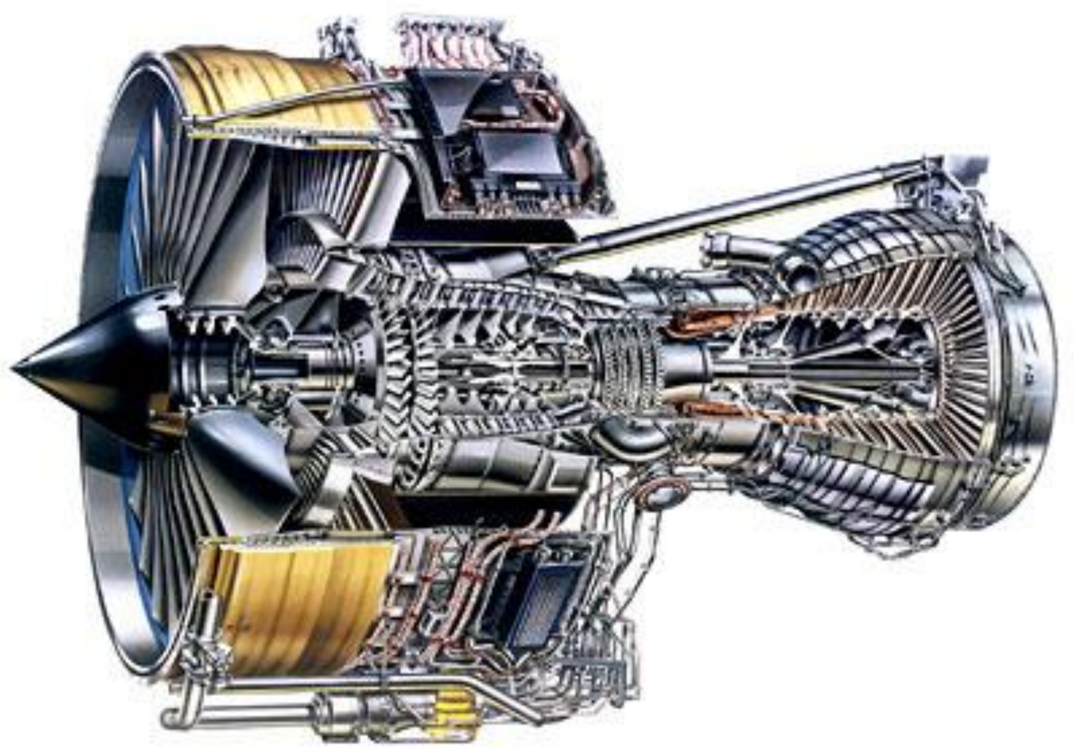


Figure 1.3 - Rolls Royce 892 engine

According to the manufacturer data, this is the lightest engine ever used on aircrafts. Compared to the GE90, it weighs 3.6 tons less. In total, the weight of this engine is 6.1 tons.

1.3 Airplane centre of gravity calculation

1.3.1 Trim sheet of equipped wing

Some factors such as mass of its structure, mass of fuel, mass of equipment placed in a wing affects on the total mass of the equipped wing. Regardless of the main landing gear attaches to the fuselage or to the wing, it's included into the mass of the equipped wing. The trim sheet contains equipment of systems, mass of the wing structure, mass of the fuel and their center of gravity coordinates.

The recomedation was taken into account for the position of the centre of masses acordint to the leading edge of a mean aerodynamic chord, the positive direction to the back or (tail direction) and negative direction from the leading edge of the MAC to the nose of the aircraft. The all masses of the wing for designed aircraft are represented in Table 1.3. For calculation of the center of gravity coordinates of equipped wing we use the formula:

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

Table 1.3 - Trim sheet of equipped wing

N	Name	Mass		C.G. coordinates, x_i (m)	Moment $m_i\, x_i$ (kgm)
		Units	total mass m_i (kg)		
1	Wing (structure)	0,11	37663,97	3,46	130317,33
2	Fuel system, 40%	0,01	1711,99	3,23	5531,47
3	Control system, 30%	0,001	372,61	4,62	1721,47
4	Electrical equip. 10%	0,002	681,44	0,77	524,17
5	Anti-icing system 70%	0,01	3887,24	0,77	2990,07
6	Hydraulic system, 70%	0,01	2762,69	4,62	12763,65
7	Power units	0,07	24367,45	2,92	71152,9
8	Equipped wing without fuel and LG	0,21	71447,41	3,15	225001,1
9	Nose landing gear	0,003	887,55	-8,59	-7624,09
10	Main landing gear	0,03	10206,87	3,93	40143,61
11	Fuel	0,36	121417,63	3,23	392300,35
	Equipped wing	0,61	203959,46	3,19	649820,98

1.3.2 Trim sheet of equipped fuselage

For the fuselage the origin point for the centers of gravity coordinations located on the projection of nose part of fuselage to horizontal axis.

The list of masses of the main objects of the fuselage is given in table 1.4.

For calculation of the center of gravity coordinates we use the formula:

$$X_f = \frac{\Sigma m_i' X_i'}{\Sigma m_i'};$$

After determinining the center of gravity of fully equipped wing and fuselage, it is necessary to construct the moment equilibrium equation relatively fuselage nose:

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

Table 1.4 - Trim sheet of equipped fuselage masses

№	Objects	Mass		Coordinates of C.G., m	Moment (kgm)
		Units	Total (kg)		
1	Fuselage	0,08	25807,54	36,95	953588,59
2	Horizontal TU	0,01	3467,64	2,19	7594,12
3	Vertical tail unit	0,01	3434,07	2,73	9375,01
4	Anti-icing system,15%	0,003	926,49	59,2	54848,41
5	Air-conditioning 15%	0,002	520,31	36,95	19225,58
6	Heat and sound isolation	0,004	1409,88	36,95	52095,11
7	Control syst 70%	0,003	869,43	36,95	32125,32
8	Hydraulic sys30%	0,003	1097,69	51,73	56783,67
9	Electrical eq, 90%	0,02	5461,61	36,95	201806,53
10	Radar	0,002	537,1	2,1	1127,90
11	Air-navig. System	0,002	772,08	6,3	4864,09
12	Radio equipment	0,001	436,39	2,2	960,06
13	Instrument panel	0,002	671,37	3,4	2282,67
Passenger aircraft					
14	Seats of pass. economical class	0,01	2641,85	42,2	111486,02
15	Seats of pass. business class	0,003	872,78	19,68	17172,02
16	Seats of crew	0,0003	100,71	12,16	1224,18

The end of table 1.4

17	Seats of flight attendance	0,001	449,82	7,39	3324,16
18	common equipment	0,001	449,82	7,39	3324,16
19	additional equipment	0,001	375,97	17,39	6538,09
Payload					
20	Mail/Cargo	0,12	38536,75	14,03	540574,3
21	Flight Attendance	0,002	772,08	12,43	9593,84
22	Baggage	0,02	7385,1	36,95	272879,15
23	Meals	0,0008	268,55	61,4	16488,9
24	Passangers	0,1	34239,97	26,21	897532,39
25	Crew	0,0004	134,27	3	402,82
	Total	0,39	335686	9,77	3281090,03

After we have determined the location of the wing relative to the fuselage, it is necessary to connect the wing with the fuselage. Only after that we calculate the location of the centers of gravity of all equipment of the wing with a new origin in the nose of fuselage (table 1.5).

Table 1.5 - Center of gravity position of the aircraft

Name	Mass, kg	Coordinates	Moment
Object	m_i	C.G. M	Kgm
Equiped wing without fuel and L.G.	71447,41	12,44	225001,09
Nose landing gear (retracted)	887,56	36,95	-7624,09
Main landing gear (retracted)	10206,87	26,21	40143,61
Fuel	121417,63	61,4	392300,35
Equiped fuselage	50389,83	7,39	1543618,64
Seats of economical class	2641,85	19,68	111486,02
Seats of bussines class	872,78	42,2	17172,02
Meals	268,55	61.42	16488,89
Baggage	7385,09	36.95	272879,15
Cargo	38536,75	14.03	540574,29
Crew	134,27	3	402,82
Attendants	772,08	12.43	9593,84
Nose landing gear (opened)	887,55	-8.59	-7624,09
Main landing gear (opened)	10206,87	3.93	40143,61

The centering - is the position of the center of gravity of the aircraft relative to the leading edge of mean aerodynamic chord, expressed in a percentage.

$$\bar{x}_T = \frac{x_T - x_A}{b_A} 100\%$$

To optimize the calculations, it is necessary to enter the corresponding coordinates of the centers of mass of the table 1.5.

The final results of the centre of gravity calculation are the positions of centre of gravity of the aircraft for different variants of operation, presented in the table 1.6.

Table 1.6 - Airplane’s centre of gravity position variants

№	Variants of the loading	Mass, kg	Moment of the mass, кg*m	Centre of the mass, m	Centering
1	Take-off mass (L.G. opened)	335686	2654336	7,91	0.23
2	Take-off mass (L.G. retracted)	335686	2734417	8,15	0.22
3	Landing variant (L.G. opened)	227514	2342181	10,29	0.2
4	Transportation variant (without payload)	145996	1810751	12,4	0.17
5	Parking variant (without fuel and payload)	136446	1801209	13,2	0.16

So, the most forward centre of gravity is located on the 16% from the leading edge of the mean aerodynamic chord, and the most aft centre of gravity on the 23%.

Conclusions to the main part

In this part of my diploma work the preliminary design of a long range aircraft with high passenger capacity was developed. We have calculated the geometrical dimensions of the main parts of the aircrafts, such as wing, fuselage, tail unit, landing gear and have chosen the Rolls-Roys Trent 892 engine. Designed aircraft accommodates up to 460 passengers, their luggage and some mail or cargo.

I chose the type of tires with dimensions 52×R22.36 PR for the designed aircraft. This is the most suitable option, since each tire from the main six-wheel rack can withstand up to 27 tons of load.

Also the most forward and the most aft centre of gravity position is located in the correct dimensions for such types of the aircraft.

2. Pilot seat conceptual design

2.1 General requirements to the design of pilot seat

During aircraft designing it is necessary to solve some tasks:

- to provide required geometrical parameters of pilot seat;

- to provide required strength characteristics;

- to provide security characteristics (loads on the spine and hips are not exceeded, maintaining the position of the shoulder and waist belts on the shoulders and pelvis of a person, ensuring that the normalized efforts in the shoulder belts).

According to the airworthiness standards FAR 25 the main requirements to the pilot seat are:

- Each pilot seat must be designed for the reaction forces resulting from the efforts exerted by the pilot.

- Each seat must have a combined restraint system, consisting of a belt and shoulder belts with a single-point release system, which allows the pilot to perform all the functions necessary in flight.

- Each seat should be designed for a 77 kg person, taking into account the maximum load factor, inertia forces and the reaction between the person, the seat, the waist belt and the seat belt for each appropriate loading condition in flight and on the ground.

- Any traumatic hazardous objects must be moved beyond the limits of movement of the pilot's head.

- Each seat should be equipped with an energy-absorbing support that supports the arms, shoulders, head and spine.

2.2. General description of the designing pilot seat

Pilot’s seat is an assembly. It consists of seatback structure (Figure 2.1). The seatback is designed to maintain the pilot’s spine and can recline. It depends on pilot’s comfort. The other part of the assembly is the seat (Figure 2.2). It can also be adjusted by raising and lowering. The pilot's comfort during long range flights has a great importance; therefore, the seat construction also has a special soft coating.

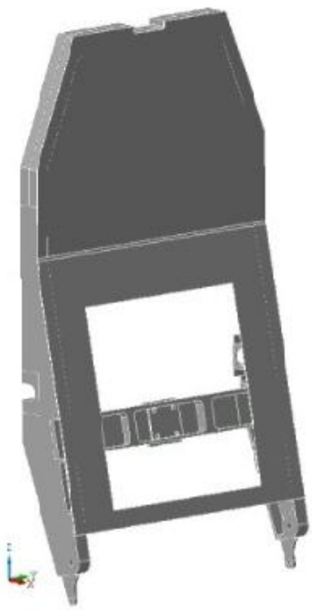


Figure 2.1 - Seatback construction.

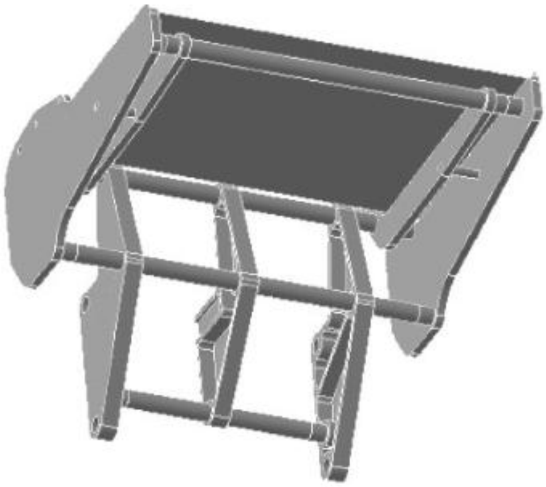


Figure 2.2 - Seat construction.

There is one more additional adjustable element of pilot seat construction for providing pilot’s comfort - it’s armrest (Figure 2.3). The armrests are individually stowable and adjustable. Each armrest has an adjusting wheel on the underside of the armrest. To deploy the armrest, slide the armrest out from the seat back and rotate it down into position. To raise and lower the armrest position, turn the adjusting wheel on the underside of the armrest. The armrests will adjust 15 to 26°. To stow the armrests for entry and exit, lift the armrest until it is parallel with the seat back and push it in toward the seat spine.

Figure 2.3 - Armrest design

The seat base (Figure 2.4) is attached to the rails (Figure 2.5) on the seat tracks. The seat bottom is located above the seat base and provides controls for forward/aft movement, seat height adjustment and seat back reclining adjustment. The seat back contains the lumbar adjustment control, adjustable armrests and an adjustable headrest. The crew seats are constructed of lightweight alloys covered with foam padding and sheepskin and are equipped with a five point restraint system.

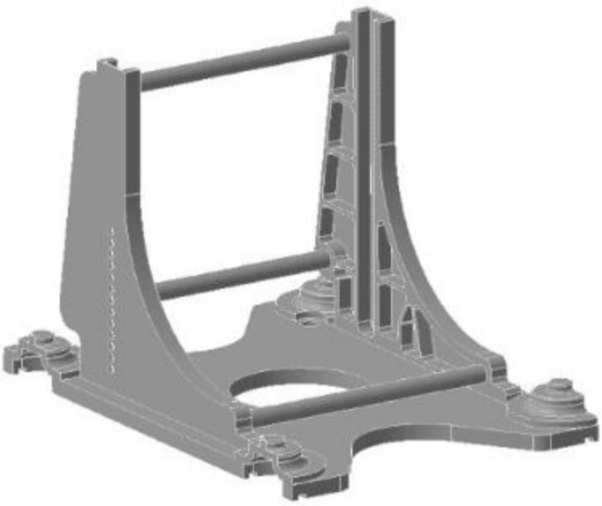


Figure 2.4 - Seat base designing

Figure 2.5 - Rail construction

For the aircraft I chose the pilot seat of Ipeco Company like prototype's seat. In real life it looks like the next example, showed in the figure 2.6.

Figure 2.6 - Pilot's seat real view: 1 – headrest, 2 – seatback, 3 – seat bottom, 4 – armrest, 5 – pocket, 6 – seat base, 7 – rails, 8 – recline adjustment control, 9 – lumbar adjustment handwheel, 10 – straps.

For the designed aircraft, the pilot seat gives comfort to the flight crew during flight. The seat is cushioned, upholstered-type seats that are adjustable and attached to floor-mounted tracks.

The main controls are located on the right side of the captains seat and the left side of the first officer's seat. The control mechanisms move the seat forward and aft, down and up. The upper section of the seat has these control mechanisms that adjust the seat for comfort and safety.

• Seat height

• Thigh pad position

- Seat recline
- Armrest height and stowage
- Lumbar support (back cushion) position
- Headrest position.

The bottom of the seat support has bogies that attach the seat to the floor-mounted tracks. The seat is adjusted in the aft/forward or the inboard/outboard direction by the shape of the floor-mounted tracks. A spring-loaded track lock safeties the seat in the necessary position.

The seat height lock lever controls the seat height. Pull the height lock lever to lower or lift the seat. Release the height lock lever to lock the seat in the correct position.

The track lock lever controls the seat forward and aft positions. Pull the track lock lever to unlock the track lock pin from the track. Move the seat forward or aft to the correct position. Release the track lock lever to lock the seat in its position.

The forward section of each seat bottom can be adjusted to lower or lift the thighs to give support. Turn the thigh pad adjustment hand wheel to lower or lift the thigh pads.

When the foot controls are used, the pressure on the thigh pad overrides the position of the thigh pad and lets the thigh pads move. When pressure is released on the foot controls, the thigh pads go back to their set position.

To recline the seat, pull the recline lever up while you move your body back until the seat is in the correct position. To return the seat to the vertical position, lean forward and pull the recline lever up until the seat is in the correct position.

The outboard armrest has height adjustment knobs that are located under the left and right forward end of the armrests. To adjust the armrest, turn the knob and move the armrest up or down.

To stow the armrest, lift the front of the armrest until it stops. When the armrest is up as far as it will go, push the armrest to the center of the seat.

The two lumbar support hand wheels are on the left and right side of the seat. The hand wheels adjust the position of the lumbar supports. The hand wheel on the left side of the seat lowers or lifts the lumbar support cushion. The hand wheel on the right side of the seat adjusts the seat cushion in the outer or inner direction.

To adjust the headrest, push and hold the lock mechanism on the right side of the headrest to unlock the mechanism. Move the headrest to the correct height. Release the lock mechanism to lock the headrest in its position.

Using the control levers, the chair should move forward, backward, up and down. These levers are located on the base of the grandmother.

2.3. Strength calculation of the pilot seat

Designing process contains several stages such as:

- Seat’s construction development in accordance with requirement geometrical parameters and safety requirements;
- Experimental testing pilot’s comfort;
- Experimental seat’s static strength testing;
- Experimental testing seat’s dynamic strength;
- Experimental material flammability and toxic testing;
- obtaining approval documents for the use of this type of seats on samples of aircraft.

During operation the seat is exposed by wo types of loads.

It is load factor along flight direction. All structural elements of the structure work in the elastic zone of deformation, but plastic deformation does not occur after unloading, since the stress in the structure does not exceed the yield strength of the material.It’s called static load. According to FAR 25 the load factor for all directions is taken like:

- Forward – 3g,
- Side – 4g,

- Up – 3g,
- Down – 6g,
- Back – 1.5g.

Second type of load is called dynamic loading. The destruction of materials does not occur, since the resulting maximum equivalent stresses in the structure do not exceed the tensile strength of the material.

- Forward (if the airplane diparts of direction of flight to 10 degree) 16g;
- Down (deviation from perpendicular to the floor of the plane up to 30 degrees) 14g.

The pilot seats are fundamentally different from the passenger seats. They have a number of additional requirements according to airworthiness standards to ensure the safety and comfort of the pilot in flight. This plays an important role for long-range passenger aircraft. During designing the cockpit, ensuring the safety of the pilot is also one of the main tasks.

Pilot’s safety provides strength of seat and fuselage construction in its mounting zone. In relation to the interior, the chair should be positioned in such a way as to ensure an acceptable level of head injury criteria (HIC).

To evaluate the design of the chair and the surrounding interior from the point of view of protecting the person in the chair, special criteria have been developed that are presented in such regulatory documents as AP-25, FAR-25, CS-25, etc. To assess the level of head safety, the HIC criterion was introduced.

To quantify the HIC criterion, in accordance with AP-25, the formula is used:

$$HIC = (t2 - t1)\left\{\frac{1}{t2 - t1}\int_{t1}^{t} a(t)dt\right\}^{2.5} \leq 1000$$

where:

t_1 is the beginning of integration;

t_2 is the end of integration;

a (t) is the total acceleration of the head during the impact.

As practice shows, despite the use of a tethered system for fixing the pilot in the seat, consisting of tethered waist and shoulder belts, the head trajectory in the event of a longitudinal-side impact during an emergency landing is such that head contact with the dashboard elements is inevitable for most aircraft.

Correspondence of the design of the chair and the interior to the above requirements should be shown by dynamic tests or design analysis based on dynamic tests of a chair of a similar type. Since dynamic testing is a very time-consuming and expensive process, when designing new seats, only a static calculation of the most loaded element will be presented.

Pilot’s seat mounts on three rails and its top view is shown on Figure 2.7

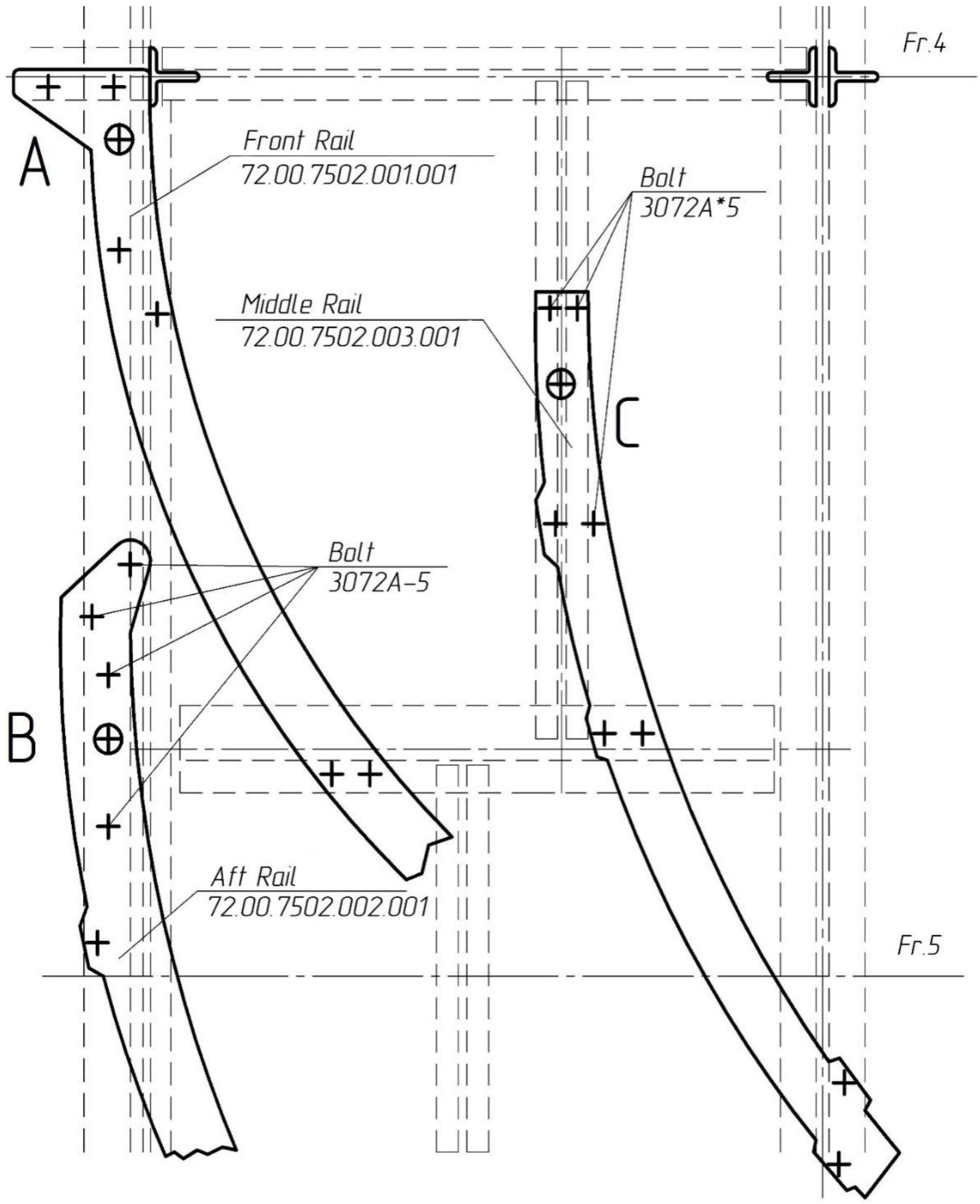


Figure 2.7 – Top view of floor eith rails under pilot seat.

Pilot’s seat loading on the rails determination.

Pilot’s weight: G_p = 80 (kg);

Seat’s weight: G_s = 15 (kgf);

Seat’s total weight:

$$G_{\Sigma} = 80+15 = 95 \text{ (kgf)};$$

Overloading calculations:

$$P_x^p = G_\Sigma \cdot n_x = 95 \cdot 9 = 855 \text{ (kgf)};$$

$$P_y^p = G_\Sigma \cdot n_y = 95 \cdot 3 = 285 \text{ (kgf)};$$

$$P_z^p = G_\Sigma \cdot n_z = 95 \cdot 4 = 380 \text{ (kgf)};$$

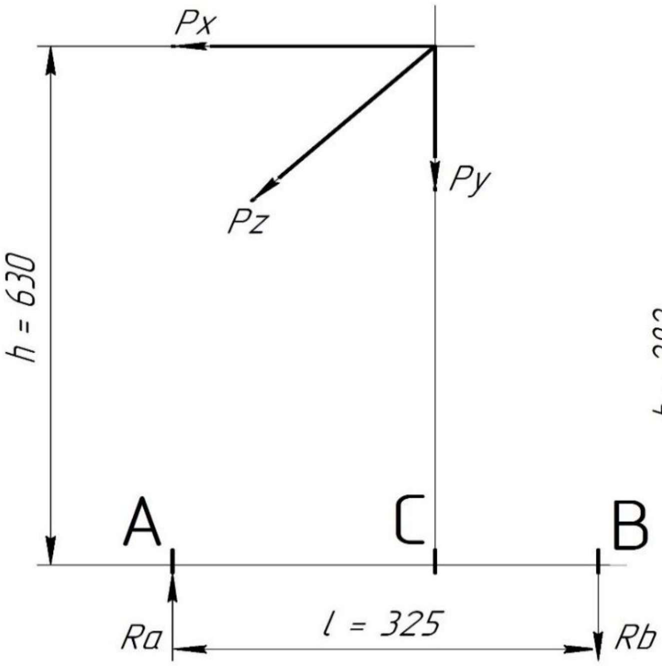


Figure 2.8 – Seat’s side view

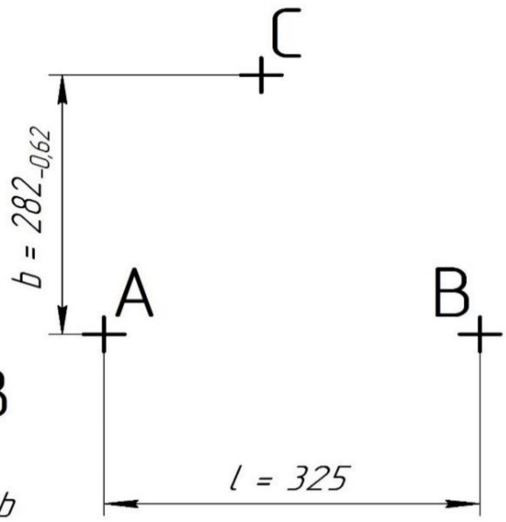


Figure 2.9 – Seat’s top view

$$-R_A^x = R_B^x = \frac{P_x^p \cdot h}{l} = \frac{855 \cdot 630}{325} = 1657 \text{ (kgf)};$$

$$R_A^y = R_B^y = R_C^y = \frac{P_y^p}{3} = \frac{285}{3} = 95 \text{ (kgf)};$$

$$R_A^z = R_B^z = R_C^z = \frac{P_z^p \cdot h}{b} = \frac{380 \cdot 630}{282} = 849 \text{ (kgf)};$$

Total reactions:

$$R_A^{\Sigma} = R_A^x + R_A^y - R_A^z = -1657 + 95 - 849 = -2311 \text{ (kgf)};$$

$$R_A^{\Sigma} = R_A^x + R_A^y + R_A^z = -1657 + 95 + 849 = -713 \text{(kgf)};$$

$$R_B^{\Sigma} = R_B^x + R_B^y - R_B^z = 1657 - 95 - 849 = 713 \text{ (kgf)};$$

$$R_B^{\Sigma} = R_B^x + R_B^y + R_B^z = 1657 - 95 + 849 = 2411 \text{ (kgf)};$$

$$R_C^{\Sigma} = -R_C^y + R_C^z = -95 + 749 = 754 \text{ (kgf)};$$

$$R_C^{\Sigma} = -R_C^y - R_C^z = -95 - 849 = -944 \text{ (kgf)};$$

Strength calculation for most loaded rear rail. Load on the rear rail at point B for rail separation is shown on Figure 2.10. The scheme of its is presented on Figure 2.11. The greatest loading on the rail calculates by the formula:

$$R_B^{\Sigma} = P_B = 2411 \text{ (kgf)};$$

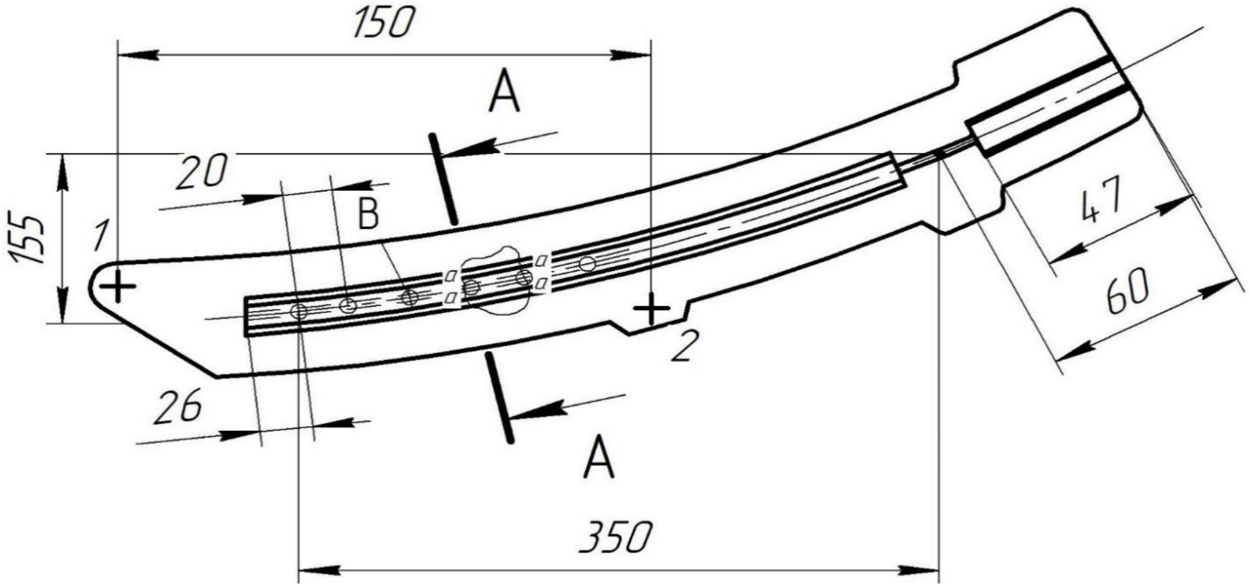


Figure 2.10 – Aft rail view

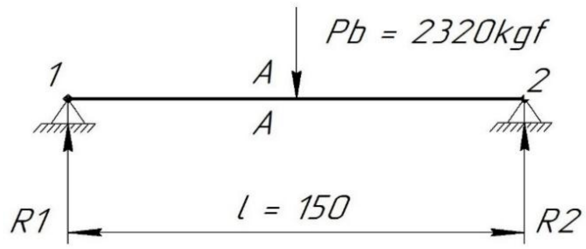


Figure 2.11 - Loaded rail section diagram

The reactions in 1 and 2 points:

$$R_1 = R_2 = \frac{P_B}{2} = \frac{2411}{2} = 1205{,}5\ (kgf);$$

A-A cross section max banding moment is shown on Picture 2.14

$$M_{A-A} = \frac{P_B \cdot l}{4} = \frac{2411 \cdot 15}{4} = 9041{,}25\ (kgf\ cm);$$

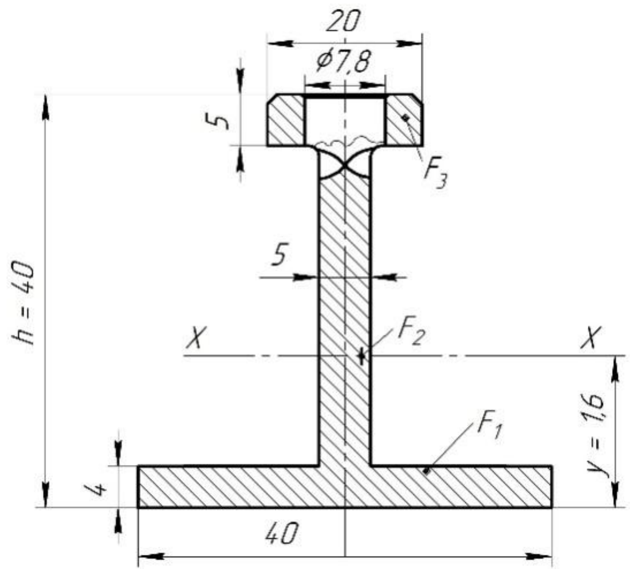


Figure 2.12 - A-A cross section geometrical characteristics

For the material: A92117: $\sigma_b = 3800(\frac{kgf}{cm^2})$. Cross section area:

$$F_{c.s.} = F_1+F_2+F_3= 4\cdot0{,}4 + 3{,}1\cdot0{,}5 + 2\cdot0{,}5 – 0{,}78\cdot0{,}5 = 3{,}76(\ cm^2);$$

Inertia moment:

$$y_{c.g.} = \frac{1{,}6\cdot0{,}2+1{,}55\cdot1{,}95+0{,}71\cdot3{,}75}{3{,}76} = 1{,}6\ (cm);$$

$$J_{x-x} = 1{,}6\cdot\ 1{,}4^2+1{,}55\cdot\ 0{,}35^2+0{,}61\cdot\ 2{,}15^2+ \frac{0{,}4^3\cdot4}{12} +\frac{3{,}1^3\cdot0{,}5}{12} = 7{,}38\ (cm^4);$$

Resistance moment of a cross section:

$$W_1= \frac{J_{x-x}}{h-y_{c.g.}} = \frac{7{,}38}{4-1{,}6} = 3{,}07\ (cm^3);$$

$$W_2= \frac{J_{x-x}}{y_{c.g.}} = \frac{7{,}38}{1{,}6} = 4{,}6\ (cm^3);$$

Maximum normal stress:

$$\sigma_{max}= \frac{M_{A-A}}{W_1} = \frac{8700}{3{,}07} = 2834\ (\frac{kgf}{cm^2}).$$

Safety factor:

$$\eta = \frac{\sigma_b}{\sigma_{max}} = \frac{3800}{2834} = 1{,}34.$$

Mounting bolts of rails loading. Three bolts separation:

$$P_{max} = P_b = 2411\ (kgf).$$

Rail’s mounting to the floor bolt with the diameter 5 mm load calculation:

$$P_{1bolt} = \frac{P_{max}}{3} = \frac{2411}{3} = 803.7 \text{ (kgf)};$$

5 mm diameter bolt breaking: $[P_{br}]$ = 1310 (kgf).

Safety factor:

$$\eta = \frac{[P_{br}]}{P_{1bolt}} = \frac{1310}{803.7} = 1.63;$$

Upper section shelf of rail between the holes for clamp calculation: P_B = 2411 (kgf) (A-A cross seection);

Its cross section is cut.

Cross secton cutted area is shown on Figure 2.13

$$F_{a-a} = 2\cdot\delta\cdot l_1 = 2\cdot 0{,}5\cdot 2 = 2 \text{ (cm}^2\text{)};$$

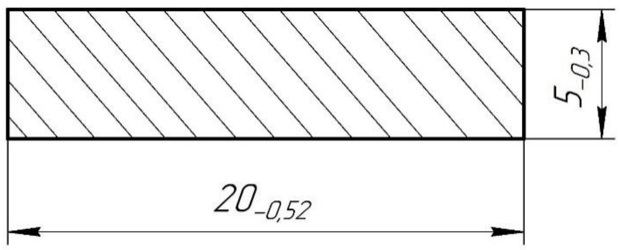


Figure 2.13 - Cross section a-a

Material: A92117 $\sigma_b = 3800(\frac{kgf}{mm^2})$;

$$\tau_b = 0{,}5\cdot\sigma_b = 0{,}5\cdot 3800 = 1900(\frac{kgf}{mm^2});$$

Shear stress in A-A cross section:

$$\tau_{a-a} = \frac{P_B}{F_{a-a}} = \frac{2411}{2} = 1205.5(\frac{kgf}{cm^2});$$

Safety coeffitient:

$$\eta = \frac{\tau_b}{\tau_{a-a}} = \frac{1900}{1205.5} = 1.58.$$

According to the calculations, safety factor is more than 1. It's mean, rails strength meets requirements, such type of material and cross section can be used for pilot's seat construction. It will be safe in flight and emergency situations.

Conclusion for the special part

In the special part of the diploma work the conceptual design of the pilot seat is presented. The short descrption of the main parts of the pilot seat and control levers and adjustment where described.

The stress analysis of the rail was performed taking into account the safety factor for the component. The aluminum alloy A92117 was chosen for the seat rail to provide nevessary strength of the seat-floor attachment and possibility to move backward-forward and in side direction.

For the designed aircraft we chose pilot seat from Ipeco British Company, which provide full procedure of the dynamc tests on the head injury criteria.

General conclusions

The presented bachelor diploma is performed according to the task and with the direction of my speciality: 134 "Aviation and Rocket-Space Engineering". The goals and aims have been accomplished in time.

The task of the diploma work was to design a long range passenger aircraft with a high number of passengers. The base prototypes was Boeing 777-300, Boeing 777-300ER and Airbus A350-1000. The analysis of prototypes, the statistic data of general aviation and the first iteration of the initial data by the special computer program give the possibility to perform the task of the work. At the main part of the diploma the preliminary design of the aircraft was presented and also the passenger cabin layout and flight cabin layout are shown. The approximate calculations of the main geometrical dimesions of the designing aircraft have been finished. Rolls Royce Trent 892 engine is taken for designed aircraft.

One of the task of the diploma work was to provide stability and control of the aircraft by the correct centre of gravity position of the aircraft for different flight and during standing on the ground. This task also was performed, and the centre of gravity position is in correct range from the mean aerodynamic chord.

To demonstrate the results of calculation the general view and layout of the aircraft was shown on the drawings.

As for the special part, it was devoted to the design of the pilot seat. The assembly dawing of it is shown, the short description and operation are presented in the notes. The stress analysis of the seat rail system shows that the taken construction made of aluminum alloy could withstand the applied loads.

References

1. 14 CFR Part 25 - Airworthiness standards: transport category airplanes https://www.law.cornell.edu/cfr/text/14/part-25

2. Karuskevich M.V., Maslak T.P. «Design of aviation machines. Modern regional turboprop». Lecture outline. – K.: NAU, 2007. – 60 p.

3. Karuskevich M.V., Maslak T.P. «Aircraft. Design». Lectures course for the students of speciality 6.070102 «Aeronavigation» – K:NAU, 2013. – 176 p.

4. Попов А.В., Шпакович Н.И., Маслак Т.П. Методические рекомендации по выполнению дипломных работ (проектов) для спец. 272 «Авиационный транспорт» специализации «Техническое обслуживание и ремонт воздушных судов и авиадвигателей». – К.: НАУ. – 2017. – 56 с.

5. Житомирский Г.И. Конструкция самолетов: Учебник для студентов авиационных специальностей ВУЗов.-М.: Машиностроение, 1991.

6. Гаража В.В. Конструкция самолетов: Учебник. – К.: КМУГА, 1998.

7. Проектирование самолетов: Учебник для ВУЗов / под редакцией Егера С.М.-М.: Машиностроение, 1983.

8. Конструкція та міцність літальних апаратів (частина 1): методичні рекомендації до виконання курсового проекту для студентів спеціальності 134 «Авіаційна та ракетно-космічнатехніка» / уклад.: С.Р. Ігнатович, М.В. Карускевич, Т.П. Маслак, С.В. Хижняк, С.С. Юцкевич. – К.: НАУ, 2018. – 91с.

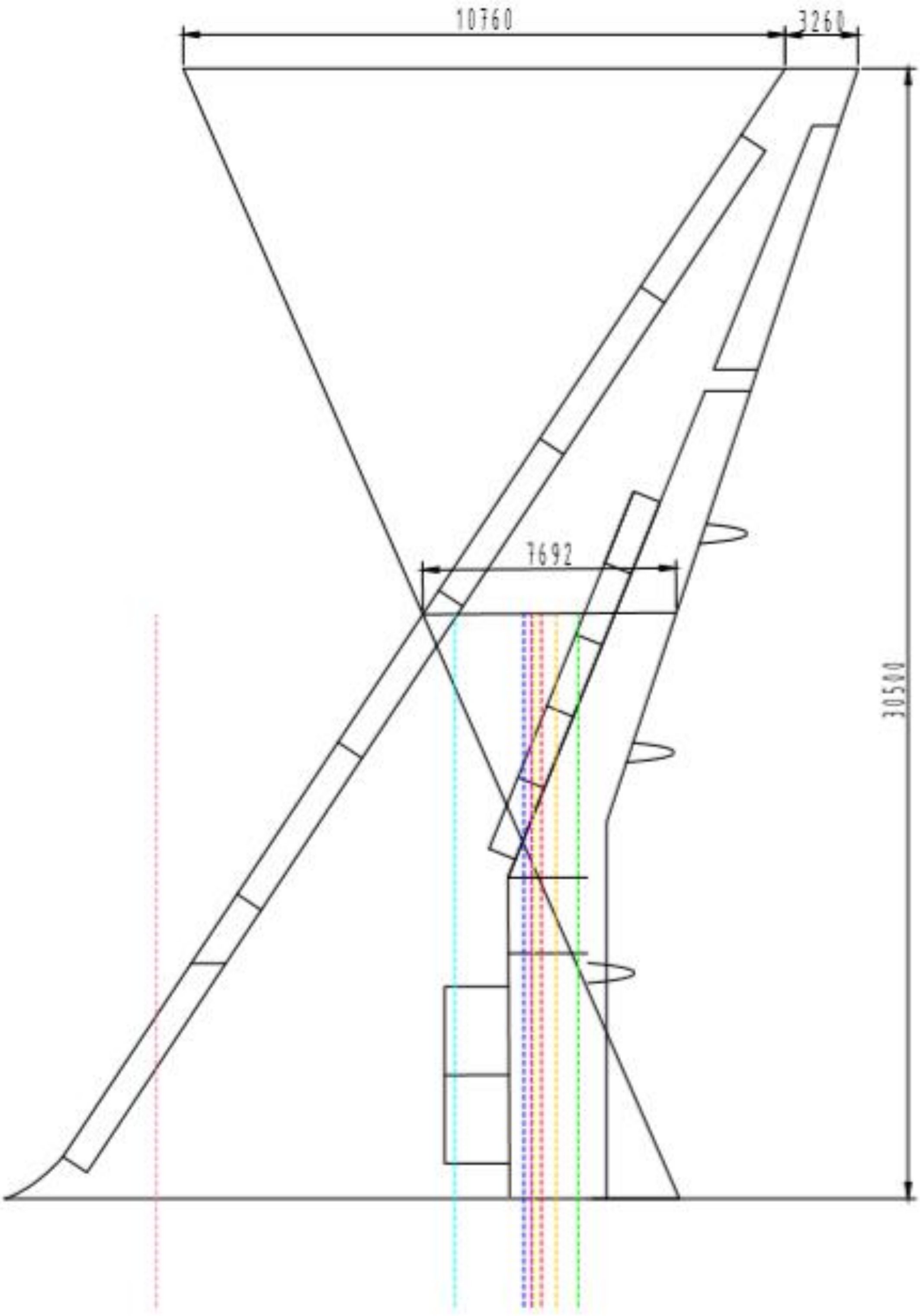
9. Конструкція та міцність літальних апаратів (частина 2): методичні рекомендації до виконання курсового проекту для студентів спеціальності 134 «Авіаційна та ракетно-космічнатехніка» / уклад.: С.Р Ігнатович, Т.П. Маслак, С.В. Хижняк, С.С. Юцкевич. – К.: НАУ, 2018. – 48 с.

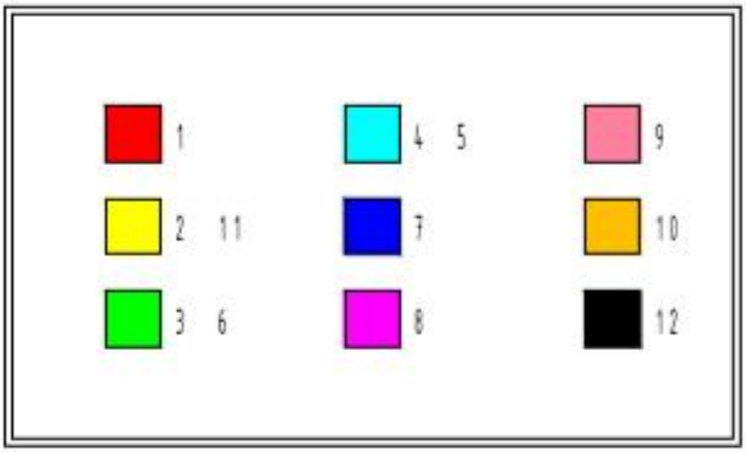
List of diploma work

Format	№	Designation	Name	Quantity	Notes
			<u>General documentation</u>		
A4	1	NAU 20 03 D 00 00 00 81 TW	Task of diploma work	1	
			<u>Graphic documentation</u>		
			Long range passenger aircraft		
A1	2	NAU 20 03 D 00 00 00 81 GV	General view	1	
A1	3	NAU 20 03 D 00 00 00 81 FL	Fuselage layout	1	
A4	4	NAU 20 03 D 00 00 00 81 EN	Explanatory note		
			<u>Documentation for assembly units</u>		
A1, A2	5	NAU 20 03 D 00 00 00 81 AD	Pilot seat assembly drawing	1	

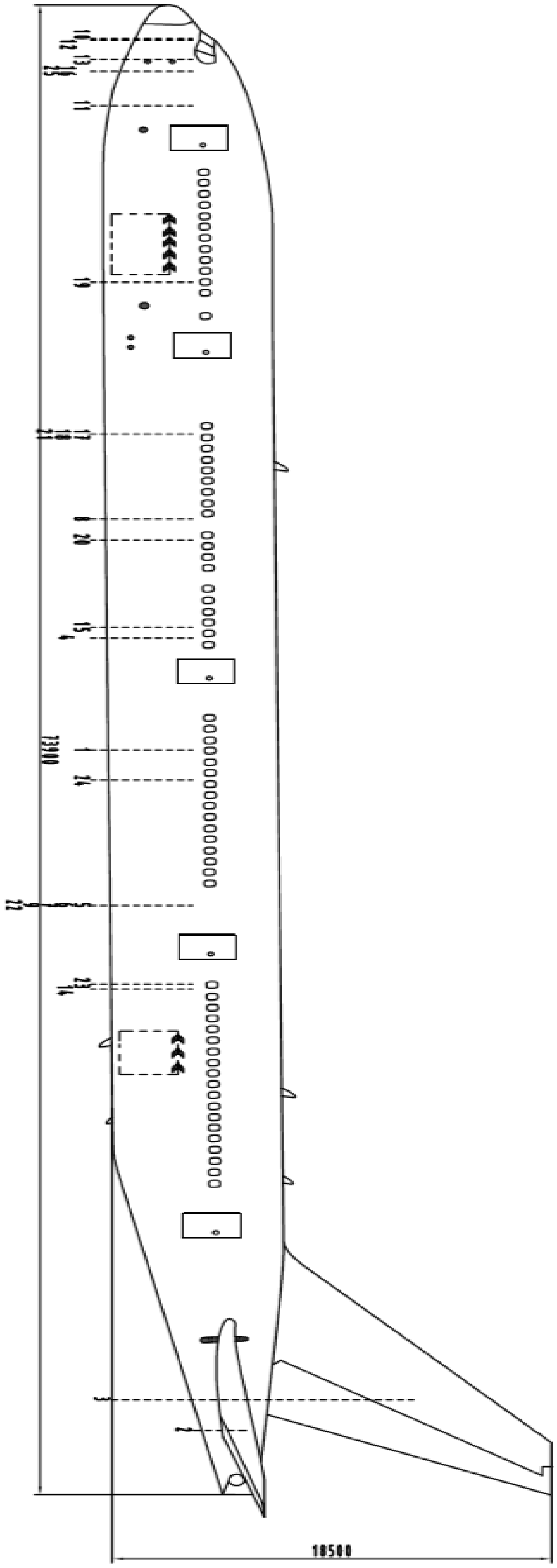
Department of aircraft design	NAU 20 02D 00 00 00 81 EN		
Done by	Dovbnia A.V.	List of diploma work	list / sheet / sheets
Supervisor	Maslak T.P.		
N. contr.	Khizhnyak S.V.		402 AF 134
Head. of d.	Ignatovich S.R.		

Appendix B





Appendix C



Appendix A

П Р О Е К Т
С А М О Л Е Т А С Т Р Д Д
Н А У, кафедра К Л А

ПРОЕКТ дипломный Расчет выполнен 04.03.2020
Исполнитель Довбня Анастасия Викторовна Руководитель Маслак Т.П.

ИСХОДНЫЕ ДАННЫЕ И ВЫБРАННЫЕ ПАРАМЕТРЫ

Количество пассажиров	460
Количество членов экипажа	2
Количество бортпроводников или сопровождающих	12
Масса снаряжения и служебного груза	6335.65 кг
Масса коммерческой нагрузки	48617.80 кг
Крейсерская скорость полета	905.км/ч
Число "М" полета при крейсерской скорости	0.8510
Расчетная высота начала реализации полетов с крейсерской экономической скоростью	13.10 км
Дальность полета с максимальной коммерческой нагрузкой	11000.км
Длина летной полосы аэродрома базирования	3.30 км
Количество двигателей	2
Оценка по статистике тяговооруженности в н/кг	2.3400
Степень повышения давления	34.00
Принятая степень двухконтурности двигателя	3.50
Оптимальная степень двухконтурности двигателя	3.50
Относительная масса топлива по статистике	0.4500
Удлинение крыла	8.70
Сужение крыла	3.30
Средняя относительная толщина крыла	0.110
Стреловидность крыла по 0.25 хорд	35.0 град
Степень механизированности крыла	0.800
Относительная площадь прикорневых наплывов	0.000
Профиль крыла - Суперкритический	
Шайбы УИТКОМБА - не применяются	
Спойлеры - установлены	
Диаметр фюзеляжа	6.20 м
Удлинение фюзеляжа	11.90
Стреловидность горизонтального оперения	35.0град
Стреловидность вертикального оперения	40.0град

Р Е З У Л Ь Т А Т Ы   Р А С Ч Е Т А
Н А У,   КАФЕДРА "К Л А"

Значение оптимального коэффициента подъемной силы в расчетной точке крейсерского режима полета Су 0.50390

Значение коэффициента Сх.инд. 0.00886

ОПРЕДЕЛЕНИЕ КОЭФФИЦИЕНТА Dм = Мкрит - Мкрейс

Число Маха крейсерское	Мкрейс	0.85104
Число Маха волнового кризиса	Мкрит	0.85693
Вычисленное значение	Dм	0.00589

Значения удельных нагрузок на крыло в кПА(по полной площади):

при взлете	5.298
в середине крейсерского участка	4.179
в начале крейсерского участка	5.078

Значение коэффициента сопротивления фюзеляжа и гондол	0.00680
Значение коэфф. профиль. сопротивления крыла и оперения	0.00888

Значение коэффициента сопротивления самолета:

в начале крейсерского режима	0.02701
в середине крейсерского режима	0.02511
Среднее значение Су при условном полете по потолкам	0.50390

Среднее крейсерское качество самолета 20.07011

Значение коэффициента Су.пос.	1.259
Значение коэффициента (при скорости сваливания) Су.пос.макс.	1.889
Значение коэффициента (при скорости сваливания)Су.взл.макс.	1.612
Значение коэффициента Су.отр.	1.177
Тяговооруженность в начале крейсерского режима	0.441
Стартовая тяговооруженность по условиям крейс. режима Ro.кр.	2.352
Стартовая тяговооруж. по условиям безопасного взлета Ro.взл.	2.953

Расчетная тяговооруженность самолета	Ro	3.100
Отношение Dr = Ro.кр / Ro.взл	Dr	0.797

УДЕЛЬНЫЕ РАСХОДЫ ТОПЛИВА (в кг/кН*ч):

взлетный	40.0184
крейсерский (характеристика двигателя)	60.9254
средний крейсерский при заданной дальности полета	66.1026

ОТНОСИТЕЛЬНЫЕ МАССЫ ТОПЛИВА:

аэронавигационный запас	0.02964
расходуемая масса топлива	0.36506

ЗНАЧЕНИЯ ОТНОСИТЕЛЬНЫХ МАСС ОСНОВНЫХ ГРУПП:

крыла	0.11261
горизонтального оперения	0.01053
вертикального оперения	0.01043
шасси	0.03305
силовой установки	0.09259
фюзеляжа	0.07888
оборудования и управления	0.09598
дополнительного оснащения	0.00749
служебной нагрузки	0.01887
топлива при Lрасч.	0.39470
коммерческой нагрузки	0.14483

Взлетная масса самолета "M.o" = 335686. кГ.

Потребная взлетная тяга одного двигателя 520.34 kH

Относительная масса высотного оборудования и противообледенительной системы самолета	0.0184
Относительная масса пассажирского оборудования	0.0108
Относительная масса декоративной обшивки и ТЗИ	0.0055
Относительная масса бытового (или грузового) оборудования	0.0154
Относительная масса управления	0.0037
Относительная масса гидросистем	0.0119
Относительная масса электрооборудования	0.0203
Относительная масса локационного оборудования	0.0017
Относительная масса навигационного оборудования	0.0026
Относительная масса радиосвязного оборудования	0.0013
Относительная масса приборного оборудования	0.0030
Относительная масса топливной системы (входит в массу "СУ")	0.0135
Дополнительное оснащение:	
Относительная масса контейнерного оборудования	0.0054
Относительная масса нетипичного оборудования	0.0021

[встроенные системы диагностики и контроля параметров, дополнительное оснащение салонов и др.]

ХАРАКТЕРИСТИКИ ВЗЛЕТНОЙ ДИСТАНЦИИ

Скорость отрыва самолета	305.43 км/ч
Ускорение при разбеге	2.52 м/с*с
Длина разбега самолета	1422. м.
Дистанция набора безопасной высоты	578. м.
Взлетная дистанция	2001. м.

ХАРАКТЕРИСТИКИ ВЗЛЕТНОЙ ДИСТАНЦИИ ПРОДОЛЖЕННОГО ВЗЛЕТА

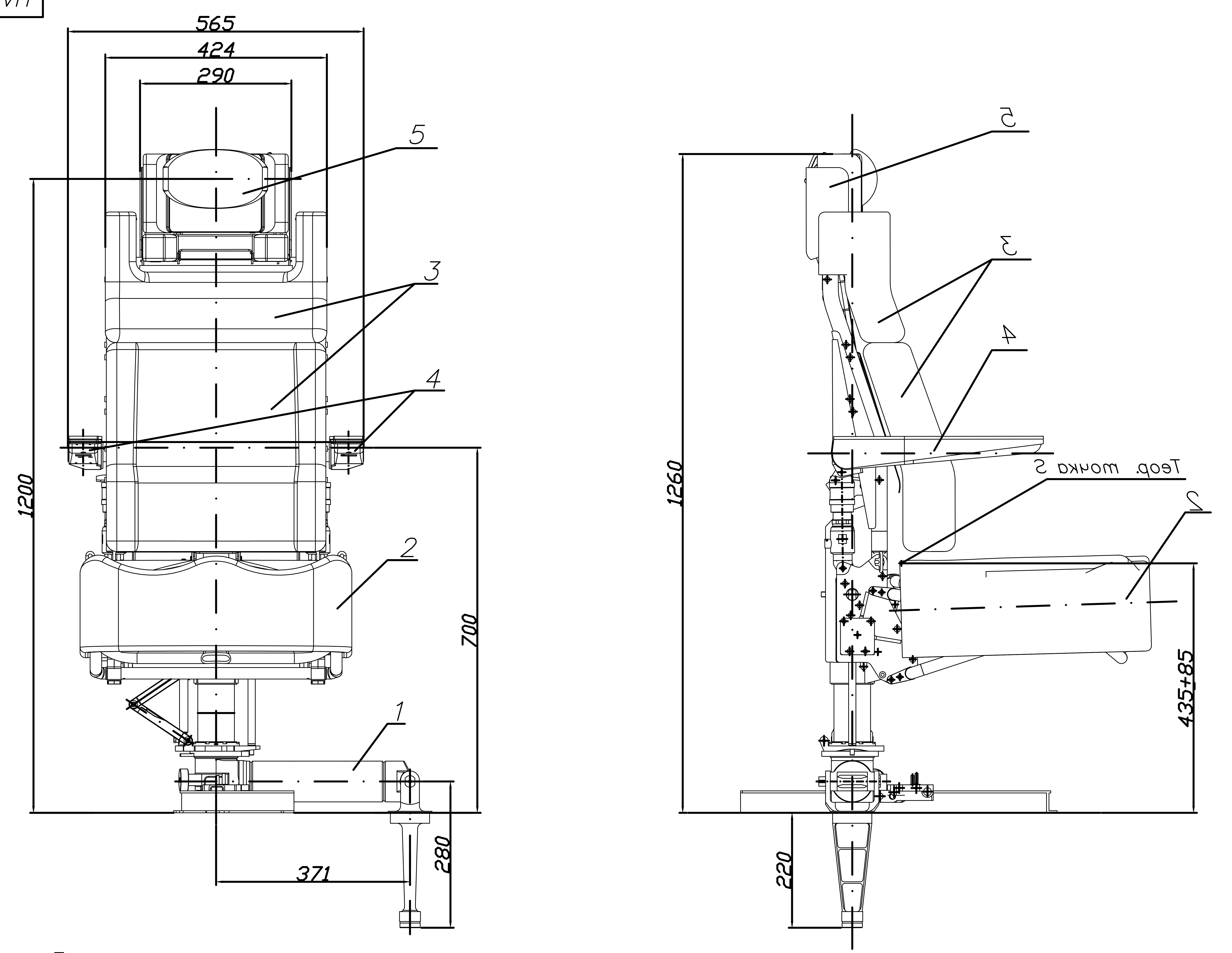
Скорость принятия решения	290.16 км/ч
Среднее ускорение при продолженном взлете на мокрой ВПП	0.45 м/с*с
Длина разбега при продолженном взлете на мокрой ВПП	2053.28 м
Взлетная дистанция продолженного взлета	2631.66 м
Потребная длина летной полосы по условиям прерванного взлета	2725.77 м

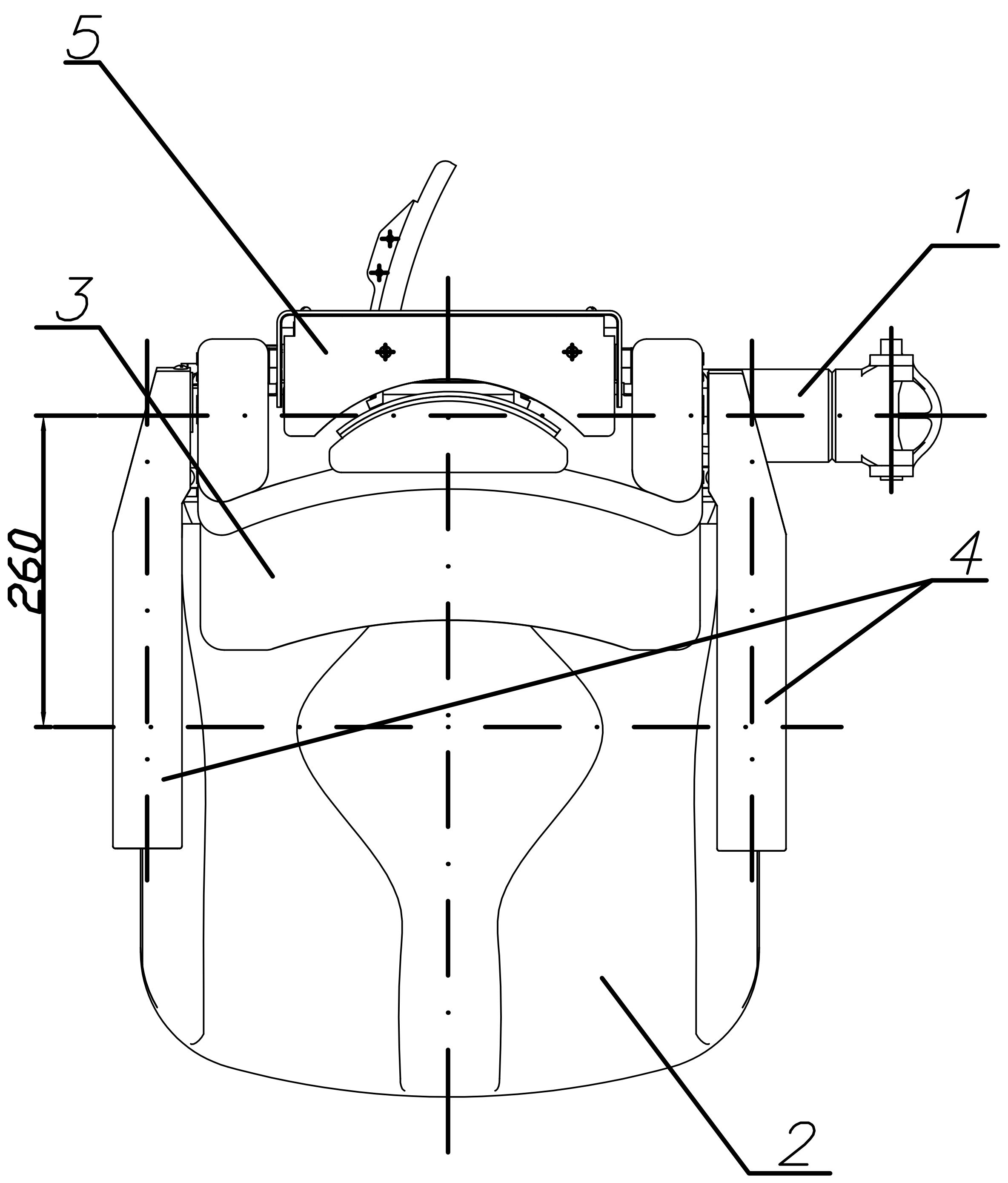
ХАРАКТЕРИСТИКИ ПОСАДОЧНОЙ ДИСТАНЦИИ

Максимальная посадочная масса самолета	230007 кг
Время снижения с высоты эшелона до высоты полета по кругу	24.3 мин
Дистанция снижения	60.99 км
Скорость захода на посадку	262.82 км/ч
Средняя вертикальная скорость снижения	2.10 м/с
Дистанция воздушного участка	522. м
Посадочная скорость	247.82 км/ч
Длина пробега	857 м
Посадочная дистанция	1379 м
Потребная длина летной полосы (ВПП + КПБ) для основного аэродрома	2303 м
Потребная длина летной полосы для запасного аэродрома	1958 м

ПОКАЗАТЕЛИ ЭФФЕКТИВНОСТИ САМОЛЕТА

Отношение массы снаряженного самолета к массе коммерческой нагрузки	3.1274
Масса пустого снаряженного с-та приход. на 1 пассажира	337.14 кг/пас
Относительная производительность по полной нагрузке	488.28 км/ч
Производительность с-та при макс.коммерч. нагрузке	42939.3 кг*км/ч
Средний часовой расход топлива	9839.361 кг/ч
Средний километровый расход топлива	11.14 кг/км
Средний расход топлива на тоннокилометр	229.146 г/(т*км)
Средний расход топлива на пассажирокилометр	21.7958 г/(пас.*км)
Ориентировочная оценка приведен. затрат на тоннокилометр	0.4368 $/(т*км)



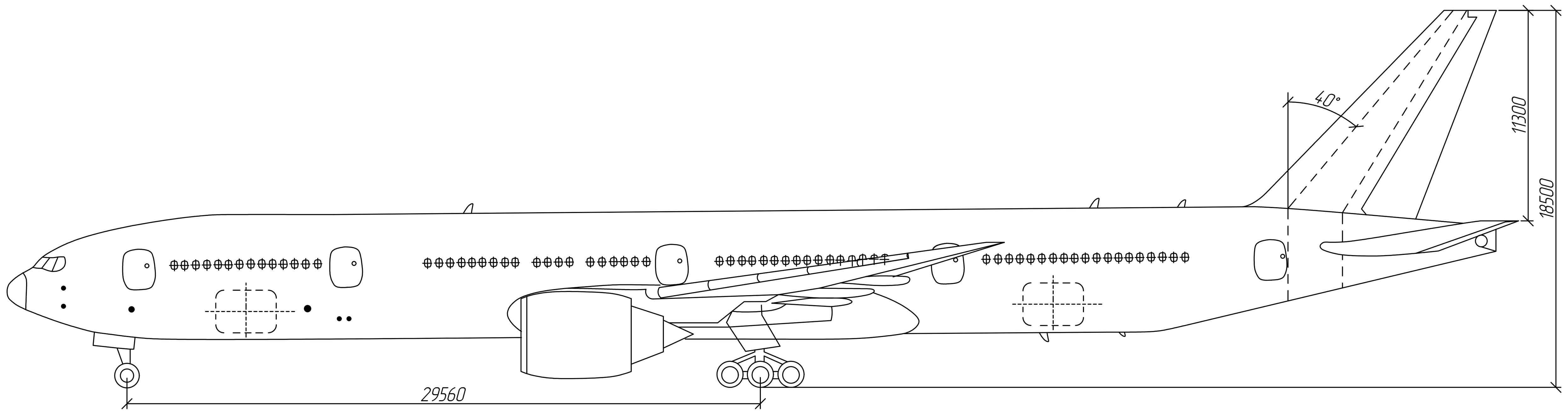


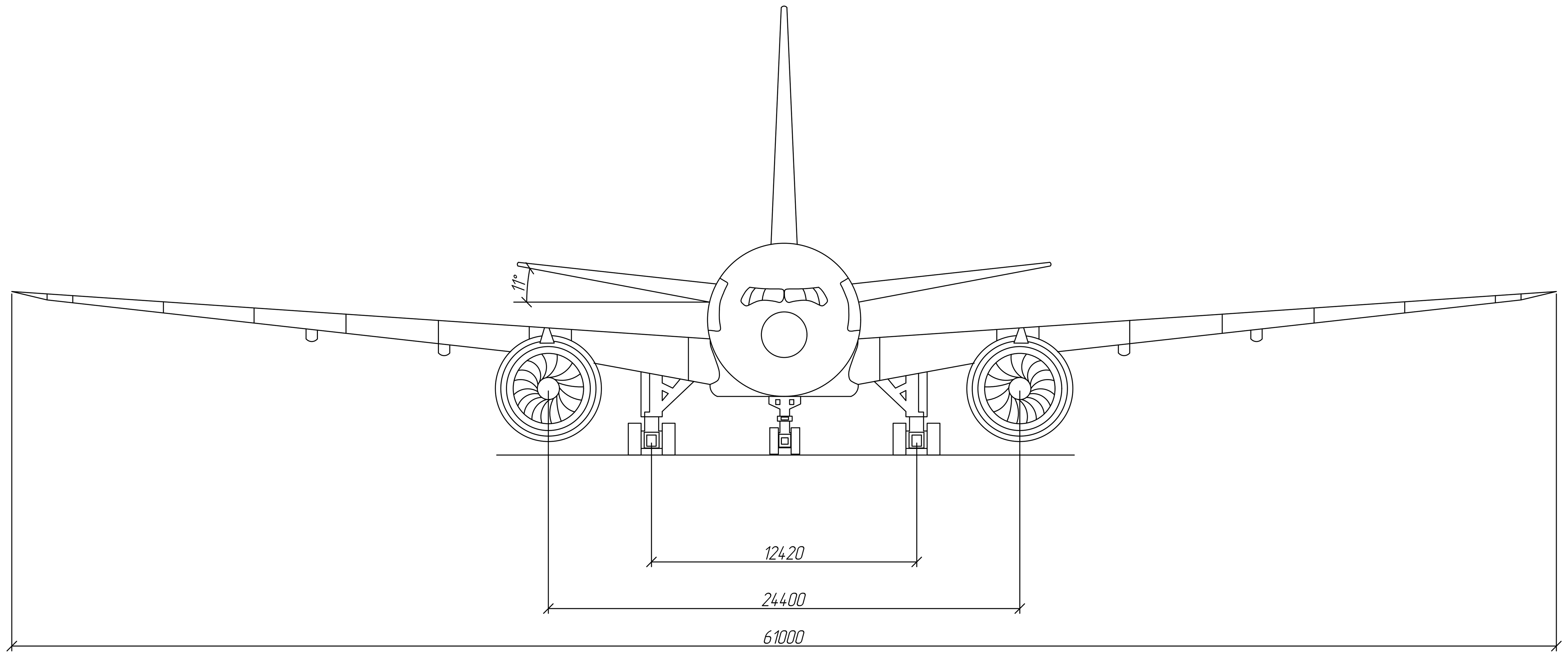
№	Sign	Name	Qty
1	NAU 20 03 D 00 00 00 4	Lever mechanism	1
2	NAU 20 03 D 00 00 00 41	Seat	1
3	NAU 20 03 D 00 00 00 44	Back Restt	1
4	NAU 20 03 D 00 00 00 45	Armrest	2
5	NAU 20 03 D 00 00 00 47	Headrest	1
6	NAU 20 03 D 00 00 00 49	Rail mechanism	1

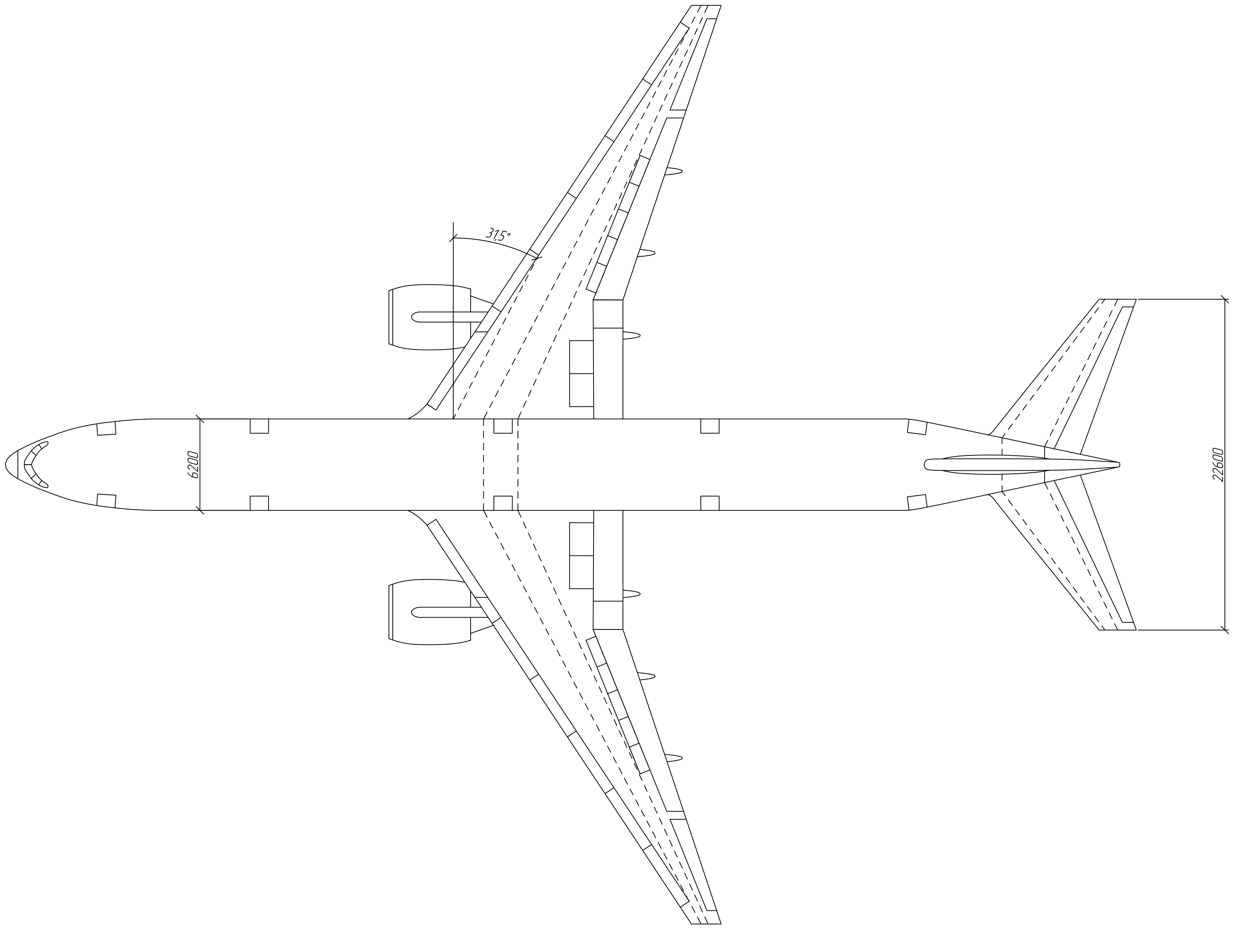
Department of aircraft design			NAU 20 03 D 00 00 00 81 PS	
		Signatyre	Date	
Perfomed by	Dovbnia A.V.			Pilot Seat
Supervisor	Maslak T.P.			Letter / Sheet 1 / Scale
Stand contr.	Khizhnyak S.V.			402AF 134
Head of dep.	Ignatovych S.R.			

№	Designation	Name	Qty
1	NAU 20 03 D 25 22 01 81 AL	Passenger seat	460
2	NAU 20 03 D 25 52 02 81 AL	Cargo compartment	1
3	NAU 20 03 D 32 11 03 81 AL	Main landing gear	1
4	NAU 20 03 D 32 21 04 81 AL	Nose landing gear	1
5	NAU 20 03 D 53 00 05 81 AL	Cockpit	1
6	NAU 20 03 D 25 11 06 81 AL	Pilot seat	2
7	NAU 20 03 D 25 40 00 81 AL	Lavatory	9
8	NAU 20 03 D 25 31 00 81 AL	Galley	6
9	NAU 20 03 D 55 10 09 81 AL	Horizontal stabilizer	1
10	NAU 20 03 D 55 30 10 81 AL	Vertical stabilizer	1
11	NAU 20 03 D 52 00 11 81 AL	Door	10
12	NAU 20 03 D 56 21 12 81 AL	Window	120
13	NAU 20 03 D 57 00 13 81 AL	Wing	1
14	NAU 20 03 D 25 21 14 81 AL	Passenger cabin	1

Department of aircraft design				NAU 20 03 D 00 00 00 81 FL			
		Signatyre	Date	Fuselage layout	Letter	Sheet	Scale
Perfomed by	Dovbnia A.V.					1	1:70
Supervisor	Maslak. T.P.						
					402 AF 134		
Stand contr.	Khizhnyak S.V.						
Head of dep.	Ignatovych S.R.						







№	Sign	Name	Qty
1	NAU 20 03 D 00 00 00 71	Locator	1
2	NAU 20 03 D 00 00 00 75	Cockpit	1
3	NAU 20 03 D 00 00 00 75	Toilet	11
4	NAU 20 03 D 00 00 00 75	Passenger cabin	3
5	NAU 20 03 D 00 00 00 75	Galley	7
6	NAU 20 03 D 00 00 00 34	Fin	1
7	NAU 20 03 D 00 00 00 33	Rudder	1
8	NAU 20 03 D 00 00 00 75	Baggage compartment	1
9	NAU 20 03 D 00 00 00 42	nose landing gear	1
10	NAU 20 03 D 00 00 00 51	Manual control	2
11	NAU 20 03 D 00 00 00 52	Foot control	2
12	NAU 20 03 D 00 00 00 32	Elevator	1
14	NAU 20 03 D 00 00 00 31	Stabilizer	1
14	NAU 20 03 D 00 00 00 75	Passenger seats	460
14	NAU 20 03 D 00 00 00 52	Foot control	2
14	NAU 20 03 D 00 00 00 32		1
14	NAU 20 03 D 00 00 00 31	Stabilizer	1
14	NAU 20 03 D 00 00 00 75	Passenger seats	

Department of Aircraft Desing	NAU 20 02 D 00 00 00 81 EN		
	Signatyre	Date	
Perfomed by	Dovbnia A.V.		General View
Supervisor	Maslak T.P.		
Stand contr.	Khizhnyak S.V.		
Head of dep.	Ignatovych S.R.		

Letter	Sheet	Sheet 's
	1	1

402AF 134