МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Кафедра конструкції літальних апаратів

ДОПУСТИТИ ДО ЗАХИСТУ

Завідувач кафедри

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«_____» ___________ 2020 р.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ

"БАКАЛАВР"

Тема: «Аванпроект середньомагістрального літака пасажиромісткістю до 100 осіб»

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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

DIPLOMA WORK

(EXPLANATORY NOTE)

OF ACADEMIC DEGREE
«BACHELOR»

Theme: «Preliminary design of middle range aircraft with a capacity of up to 100 passengers»

Performed by: __________R.A. Ihnatov

Supervisor: PhD, associate professor __________ V.I. Zakiev

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

TASK
for bachelor diploma work
IHNATOV ROMAN

1. Theme: «Preliminary design of middle range aircraft with capacity of up to 100 passengers»

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

3. Work initial data: cruise speed V_{cr}=820 km/h, flight range L=2500 km, operating altitude H_{op}=12 km, passenger capacity is 90

4. Explanation note argument (list of topics to be developed): introduction; the analytical part: choice and substantiations of the airplane scheme, choice of initial data; the project part: engine selection, aircraft layout, center of gravity position.

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

Graphical materials are performed in AutoCad.

6. Calendar Plan

Task	Execution period	Signature
Task receiving, processing of statistical data	25.05.2020-26.05.2020	
Aircraft take-off mass determination	27.05.2020-29.05.2020	
Aircraft layout	30.05.2020-04.06.2020	
Aircraft centering determination	04.06.2020-08.06.2020	
Preliminary defence	13.06.2020-21.06.2020	

7. Task issuance date: 25.05.2020

Supervisor of diploma work __________ V.I. Zakiev

Task for execution is given for __________ R.A. Ihnatov

ABSTRACT

Explanatory note to the diploma work «Preliminary design of middle range aircraft with capacity of up to 100 passengers» contains:

69 sheets, 10 figures, 11 tables, 10 references and 3 drawings

Object of the design is development of middle range aircraft with the possibility to accommodate 90 passengers.

Aim of the diploma work is the development of the aircraft preliminary and its design characteristic estimation.

The method of design is analysis of the prototypes and selections of the most advanced technical decisions.

The diploma work contains drawings of the aircraft for corporate transportation, calculations and drawings of the aircraft layout and lever.

AIRCRAFT, PRELIMININARY DESIGN, LAYOUT, CENTER OF GRAVITY POSITION, LEVER

List of diploma work

Format	№	Designation	Name	Quantity	Notes
			General documents		
A4	1	NAU 20 06 I TW	Task of project	1	
A1	2	NAU 20 06 I 00 00 00 78 GV	Middle range passenger aircraft. General view	1	
A1	3	NAU 20 06 I 00 00 00 78 AL	Fuselage layout	1	
A4	4	NAU 20 06 I 00 00 00 78 EN	Middle range passenger aircraft.	69	
			Explanatory note		
			Documentation for assembly units		
A1	5	NAU 20 06 I 00 00 00 78 SP	Lever construction	1	

Department of Aircraft Design				**NAU 20 06 I 00 00 00 78 EN**		
Performed by	Ihnatov R.			**Middle range passenger aircraft. (List of diploma work)**	list	sheet	sheets
Supervisor	Zakiev V.						
Adviser					**402AF 134**		
Stand. contr.	Khizhnyak S.V.						
Head. of dep.	Ignatovich S.						

Content

Introduction …………………………………………………………………………..
1 Analysis of prototypes and description of designing aircraft…………………….
1.1 Choise of the project data…………………………………………………………
1.2 Description of the main parts of the aircraft………………………….................
1.2.1 Wing ……………………………………………………………........................
1.2.2 Fuselage………………………………………………………………..............
1.2.3 Crew cabin ………………………………………………………………………..
1.2.4 Control system ………………………………………………………………....
1.2.5 Power plant …………………………………………………………………….
1.2.6 Tail unit………………………………………………………..........................
1.2.7 Passenger furnishing……………………………………………………………
1.2.8 Landing gear…………………………………………………………………….
1.3 Aircraft layout and center of gravity calculation………………….....................
1.3.1 Geometry calculations for the main parts of the aircraft …………………...
1.3.2 Fuselage layout …………………………………...
1.3.3 Galleys and buffets …………………………………………………………….
1.3.4 Layout and calculation of basic parameters of tail unit…………….............
1.3.5 Choice and description of power plant ……………………………….........
1.3.6 Wing geometry calculation ……………………………….........................
1.3.7 Luggage compartment ………..
1.3.8 Lavatories………………………...
1.3.9 Landing gear design ……………………………………………………………..
1.4 Aircraft center of gravity position determination ……………………………
1.4.1 Determination of the centering of the equipped fuselage …………………..
1.4.2 Determination of centering of the equipped wing ………………………….

Aircraft Design Department				*NAU 20 06 l 00 00 00 78 EN*			
Performed by	*Ihnatov R.*			*CONTENT*	*Letter*	*Sheet*	*Sheets*
Supervisor	*Zakiev V.*						
Adviser					*402 AF 134*		
Stand.contr.	*Khizhnyak S.V.*						
Head of dep	*Ignatovych S.*						

1.4.3 Calculation of center of gravity positioning variants……………………….

Conclusion to the part 1……………………….……………….......................

2.1 Strength calculation of the lever ……………..…………………….……...

2.1.1 General description of handrail and struts …………...………….…………

2.2 Define the calculated forces acting in the struts ………………………….……

Conclusion to the part 2……………………...……………………...............

Conclusion.……………………..……………..

References………………………………………………………….................

Appendix A…...…………………………………………………..……..................

Appendix B…...…………………………………………………..……..................

Appendix C…...…………………………………………………..……..................

Appendix D…...…………………………………………………..……..................

INRTODUCTION

Currently, business aviation is an important part of the service sector, represented by airlines and aircraft manufacturers. This is a civil aviation industry that specializes in the design, manufacture, operation and maintenance of aircraft for individual and corporate flights. This type of aircraft is primarily intended for the transport of government officials and commercial organizations. Business aviation has a passenger cabin in which the heads of delegations and their wards can be accommodated with a high degree of comfort. The individual layout of the cabin is also adapted for emergency meetings and communication to solve unsaleable tasks. They are equipped with the latest technologies that allow passengers to work comfortably during the flight, without the need for additional equipment. Corporate or private aircraft were originally based on serial passenger liners or transport aircraft with a redesigned cockpit. This gives an economic advantage, saving money on the development of a completely new aircraft. The type of aircraft depends on the needs of the consumer, the method of operation and use of the business jet. It can be private property, charter or partial property. The main advantages of using business aviation are:

-Time saving by providing direct flights and minimal waiting time due to the use of VIP terminals at airports.

-The possibility of working meetings and solving problems directly during the flight.

-The possibility of individual planning of the flight schedule, which allows in the shortest time to achieve the necessary aim. Air carrier independence.

-Using routes that are not included in the scheduled flights of the airline company, for example, in regional airports.

Advantages of using my prototype is based on its construction, that gives opportunity of operating in non-typical conditions. It is a high wing monoplane with a high engines location. Has a specially designed landing gear, providing a short run-up during take-off and landing. It gives a possibility of operating in difficult conditions on short unpaved runways, with terminals not suitable for this class of aircraft and on aerodromes with non-developed infrastructure. Without the need to use auxiliary equipment for loading and unloading passengers due to the presence of a door-ramp. It prototype has significant advantages over competitors in price and fuel consumption when installing the original layout of the power plant. The aircraft must satisfy all requirements relating to airworthiness and ICAO standards. It is also necessary to provide safety operation of aircraft, maintainability, must meet environmental standards and be comfortable. The theme of my diploma work is the creation of the aircraft for corporate transportation, which will meet all the above listed criteria and conditions.

PART 1

1.1 Choise of the project data

It is necessary to determine the design parameters of the aircraft, aimed at shaping the appearance of the projected aircraft. We should choose the most optimal economical geometrical, technical, aerodynamical and weight characteristics. Statistical data, prototyping and approximate aerodynamic dependencies are used. The second stage is a full aerodynamic calculation, performed by the program method.

Prototypes of the aircraft, taking for the designing aircraft were in range of capacity up to 75-100 passengers. Such aircraft like Ан 148-100, Bae 146 and Ан168 will compete with projected aircraft in this market segment. Statistic data of prototypes are presented in table 1.1.

Table 1.1 – Operational-technical data of aircraft prototypes

Name and dimensionality	AH-148	Bae 146	AH 168
Max payload	43700	42200	
Crew, [persons]	2+2(3)	2+2	
Passengers	80	85-100	12-98
Wing loading, [kN/m^2]	258-480		
Mean cruising lift-to-drag ratio			12.71946
Flight range with $G_{payload,max}$, [km]	4400	3650	7000
Range of cruising altitudes, [km]	12,2	9,5	
Thrust/weight ratio kN/kg			3.35
Specific fuel consumption [gt/km]	1,650	1,672- 2,488	

Table 1.2 - Power plant data

Number of engines and their type	2xТРДД	4xTF	2xТРДД
Take off thrust, [kN]	67	38,1	
Take off power, [kN]			66.46
Cruising thrust, [kN]	14,7		
Spec. fuel cons., take off, [kg/kN]		29	29.7
Spec. fuel cons., cruising, [kg/kN]		51	54
Pressure ratio	26,2		35
Bypass ratio	4,91	7,1	9

Table 1.3 - Take off and landing characteristics

Aerodrome code letter	B	B	
Approach speed, [km/h]	800-870	747-787	820
Landing speed, [km/h]	240		250
Speed of lift, [km/h]		265	258
Take off run distance, [m]	1885	2300	981
Landing run distance, [m]	1885		49
Take off distance, [m]		1990	1559
Landing distance, [m]		1190	1267

Table 1.4 - Airplane mass data

Take off gross mass, [kg]	43700	42184	
Landing mass, [kg]			36314
Fuel fraction, %	0.27	0,233	0.195
Payload fraction, %	0.23		0.226

Table 1.5 - Main geometrical parameters

Wing span, [m]	28.91	26,34	
Sweepback angle at ¼ of the chord, [degree]	29		27
Mean geometric chord, [m]	3,02		3,1
Wing aspect ratio	9,17	8,98	9
Wing taper ratio	2,7		2,7
Fuselage length, [m]	29,1		29
Fuselage diameter, [m]	3,5		3,5
Fuselage fineness ratio	8,3		8,3
Passenger cabin width, [m]		3.130	
Passenger cabin length, [m]		13.5	
Cabin height, [m]		2	
Seat pitch, [m]	889		1000
Aisle width, [m]		480	
Horizontal tail sweepback angle, [degree]	30		32
Horizontal tail aspect ratio	9.05		9.05
Horizontal tail taper ratio	4.93		4.93
Relative area of elevator, %	18		18
Vertical tail height, [m]	8,2		8,2
Vertical tail sweepback angle, [degree]	31		35
Landing gear base, [m]	9.6		
Landing gear track, [m]	1.65		

The relative position of the aircraft elements was determined according to the optimal conditions, logical chains of displacement and prototype. Their geometric characteristics were taken into account. Aerodynamic and operational characteristics of the aircraft depend on the layout of the aircraft and aerodynamic configuration. Chosen scheme allows to increase the economic efficiency of the aircraft , the regularity and safety of flights.

1.2 Description of the main parts of the aircraft

Aircraft An-168 is a modification of a passenger medium-range aircraft with an additional fuel tank installed at an extension beyond the center section. Designed to increase the flight range to 7000km in the cabin business layout version. It is a narrow-body high-wing monoplane with two turbofan engines installed under the wing. The high location of the engines is more advantageous for the safe system operation since it prevents entering of foreign objects into the turbine. Auxiliary power unit is present. A new system of auto diagnostics installed on board. Together, this makes possible to use the aircraft on low developed airfields and unpaved runways. Modern digital equipment and the fly-by-wire system provide an aircraft operation in conditions of poor visibility on busy routes, simultaneously satisfying safety conditions. The main landing gear is retracted into a special housing, which allows to reduce drag and improve aerodynamic characteristics. The presence of the airstairs eliminates the use of additional ground equipment.

1.2.1 Wing

Wing with a torsional box. Has a beam-type construction with walls at the front and rear, load-bearing skin – at the bottom and upper part. Skin of torsion box can take normal and shear stresses. The bending moment is taken by skin and stringers. The wing is swept, it gives us high rates of the critical Mach number and at transonic speeds reduces the phenomenon of wave crisis. It consists of a center section and two attachable wing parts connected along the ribs. The front edge of the wing is equipped with air-thermal and electrothermal anti-icing device. Hot air is supplied from aircraft engine compressors.

1.2.2 Fuselage

Fuselage design is an all-metal semi-monocoque of circular cross-section, with skin reinforcement of stringers and frames. The design of this type distributes the load on the external thin-walled shell that supports its frame.

The combination of such structural elements gives an advantage in the possibility of creating a minimum drag and a higher critical Mach number.

The cockpit is designed for two pilots, and there is also the possibility of accommodating the attendant on a specially installed seat. The first pilot is on the left, the second pilot is on the right. Before the pilots installed dashboards and screens. There is upper electrical panel above the glazing of the cabin roof. It has a side console for the first pilot, and for the second pilot.

Ahead of the first and second pilot's seats there are steering wheels for driving the elevator and ailerons and pedals for steering the rudder.

On the dashboard are mounted flight navigation instruments for monitoring the operation of the power plant, signaling devices, and so on.

There are windows and emergency exit on both sides of the passenger cabin. Luggage comparment are installed along the cabin on both sides to accommodate hand-luggage passengers. On the shelves in the lower part, there are service panels with individual ventilation nozzles, lights, buttons to turn on individual lighting. flight attendant call button and seat number illumination. Lamps for general interior lighting are located in the central part of the ceiling. Side lights and the lower part of the luggage compartment is present.

The nose landing gear, the front cargo compartment, and the rear cargo compartment are located in the non-pressurized part of the fuselage below the cabin. Cargo compartments are pressurized, each has an access door on the right side of the fuselage and is equipped with a cargo blocking system.

The main reinforced elements of the fuselage are the frame, stringers and longitudinal beams.

1.2.3 Crew cabin

The configuration of the cockpit provides control over the movement of the aircraft and its condition at any time. The stability and controllability characteristics of the aircraft, the structure and automation of the flight navigation equipment, onboard systems and display equipment ensure that pilots perform their duties without exceeding the existing load standards.

A good overview is provided by the use of conical windshields of the cockpit fairing. That meets the requirements of flight operations. There is possibility of manual and automatic control for each pilot.

The location of instruments and light-signaling devices on the pilot's control panel is carried out in accordance with the requirements of airworthiness standards. At the top of the control panel in the zone of best reach and visibility are located the quickly used control panels for command radio stations and automatic control systems.

The upper control panel of the onboard systems contains the fuel, hydraulic, power supply, anti-icing system, air conditioners, engine and APU starting, fire extinguishing switches and alarm panel.

The pilot’s central panel contains not only traditionally installed engine control levers, but also navigation and landing equipment panels.

1.2.4 Control system

The aircraft control system is provided by the rudder, ailerons, spoilers, air brakes, flaps and slats, the elevator control system and stabilizers. It includes an automatic on-board control system designed to increase the stability and controllability of the aircraft during flight in all modes. control of the aircraft.

The control system of the aircraft operates in the following modes:

- steering mode - a mode in which the aircraft is controlled by the first or second pilot through the usual movement of command levers (columns, steering wheels, pedals) when the automatic system is in operation;

- semi-automatic control mode - the mode in which the pilot controls the aircraft (using the same command levers) the position of the commander of the pilot-command tool;

- automatic control mode - the mode in which the aircraft is controlled by an automatic system in conjunction with the flight-navigation complex.

The control of the main controls is double: each pilot has duplicate control levers of the systems. Control can be performed simultaneously by two pilots and separately.

1.2.5 Power plant

The power plant: is the Progress D-436 a three-shaft high by-pass turbofan engine developed by the Ukrainian company Ivchenko-Progress. D-436-148 - modification of the engine D-436T1 with a take-off mode from 6400 to 6830 kgf. Compared to the base engine D-436T1 has a modified drive box and a reversing device, the gas generator hoods and the outer nozzle contour are made of composite materials with sound-absorbing coatings and are shortened. New automatic control system is electronic-digital with full type responsibility.

The "-148" variant was developed specifically for the An-148. This version is derated to 67 kN (15,000 lbf) of thrust for longer engine life.

1.2.6 Tail unit

Tail unit has a T-shape type, consists of a vertical and horizontal stabilizer. Vertical tail unit consist of a rudder and fin. A deflectable profile is attached to the rear edge of the vertical stabilizer, which is controlled from the cockpit. Horizontal tail consists of stabilizer and elevator for aircraft balancing. The vertical and horizontal profile of the empennage is symmetrical. Symmetrical profile ensures uniform distribution of aerodynamic loads during rudder deflection and reduces drag. To reduce the weight of the fin, which is under the action of various loads, the relative thickness of the vertical tail is increased compared to the horizontal one.

1.2.7 Passenger furnishing

Passenger equipment of the aircraft provides the necessary amenities and safety of passengers on board. It includes adjustable pilot seats, seats for flight attendants and passengers, light shutters, lavatory and galley.

A lavatory and galley are located between the crew cabin and the passenger cabin. In toilet are located tank with water and technical fluid. It is of a vacuum type. On board are 4 first-aid kits (2 in the cockpit, one is part of the emergency equipment and one - in the tail section).

Emergency equipment includes ropes, oxygen masks, smoke masks, oxygen devices, a manual fire extinguisher, first-aid kits, an ax, emergency radio stations and a radio beacon, light markings of escape routes, emergency lighting, an EXIT plate near each emergency exit, life jackets at crew sites and the observer, life rafts for crew members and passengers.

1.2.8 Landing gear

The landing gear provide support of the aircraft on the ground, the necessary position of the aircraft during parking and its movement during takeoff, landing and taxiing at the aerodrome. There is a tricycle type landing gear on the aircraft.

The advantages of this scheme are: the possibility of landing at a higher speed, easier landing and more safety of operation. This is explained by the fact that the nose strut protects the aircraft from nose-down, which also makes it possible to brake the wheels more vigorously. Moreover, “bounced landing” of the aircraft is prevented, since the center of gravity is located in front of the main wheels and when the main wheels hit, the angle of attack decrease.

The front support has two wheels and is located in front of the center of gravity, thus avoiding overturning and using more efficient wheel braking to reduce runway mileage. Pneumatics of the wheels takes the load during landing and movement on the airfield and passes it to the supports. The aircraft has a front wheel drive control system, which makes it possible to effectively maneuver the aircraft while taxiing. Wheel control is controlled by the deflection of the steering pedals.

The main legs of the gearbox have a hydraulic brake system for the wheels and devices that automatically adjust the braking force of the wheels, which eliminates the appearance of a skid.

The prevention of the appearance of a drift is due to the presence of a hydraulic braking system on the main legs that ensures effective maneuvering of the aircraft during taxiing.

1.3 Aircraft layout and center of gravity calculation

1.3.1 Geometry calculations for the main parts of the aircraft

Layout of the aircraft consists from composing the relative disposition of its parts and constructions, and all types of the loads (passengers, luggage, cargo, fuel, and so on).

Choosing the scheme of the composition and aircraft parameters is directed by the best conformity to the operational requirements.

1.3.2 Fuselage layout

During the choice of the shape and the size of fuselage cross section we need to come from the aerodynamic demands (streamlining and cross section).

Applicable to the subsonic passenger and cargo aircrafts (V < 800 km/h) wave resistance doesn't affect it. So we need to choose from the conditions of the list values friction resistance C_{xf} and profile resistance C_{xp}.

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

For transonic airplanes fuselage nose part has to be:

$$l_{npf} = 2 \times D_f = 2 \times 3{,}5 = 7 \qquad (2.17)$$

Except aerodynamic requirements consideration during the choice of cross section shape, we need to consider the strength and layout requirements.

For ensuring of the minimal weight, the most convenient fuselage cross section shape is circular cross section. In this case we have the minimal fuselage skin width. As the partial case we may use the combination of two or more vertical or horizontal series of circles. For cargo aircrafts the aerodynamics is not so important in the fuselage shape choice, and the cross section shape is may be close to rectangular one.

To geometrical parameters we concern: fuselage diameter D_f; fuselage length l_f; fuselage aspect ratio λ_f; fuselage nose part aspect ratio λ_{np}; tail unit aspect ratio λ_{TU}. 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. To geometrical parameters we concern: fuselage diameter D_f; fuselage length l_f; fuselage aspect ratio λ_f; fuselage nose part aspect ratio λ_{np}; tail unit aspect ratio λ_{TU}.

Fuselage length is equal:

$$l_f = \lambda_f \times D_f = 8{,}5 \times 3{,}5 = 29{,}75\ [m] \tag{2.18}$$

Fuselage nose part aspect ratio is equal:

$$\lambda_{fnp} = \frac{l_{fnp}}{D_f} = \frac{7}{3{,}5} = 2 \tag{2.19}$$

Sum of nose part and rear part aspect ratio:

$$\lambda_{fnp} + \lambda_{frp} = 5 \tag{2.20}$$

So, aspect ration of rear part is equal:

$$\lambda_{frp} = 5 - \lambda_{fnp} = 3 \tag{2.21}$$

Length of the fuselage rear part is equal:

$$l_{frp} = \lambda_{frp} \times D_f = 3 \times 3{,}5 = 10{,}5 \tag{2.22}$$

During the determination of fuselage length, we seek for approaching minimum mid-section S_{ms} from one side and layout demands from the other.

For passenger and cargo airplanes fuselage mid-section first of all comes from the size of passenger saloon or cargo cabin. One of the main parameter, determining the mid-section of passenger airplane is the height of the passenger saloon.

For short range airplanes we may take the height as: h_l=1.75m; passage width b_p=0.45...0.5m; the distance from the window to the flour h_2=1m; luggage space h_3=0.6...0.9m.

For long range airplanes correspondingly: the height as: h_l=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.

$$H_{cab} = 1{,}48 + 0{,}17B_{cab} = 1{,}48 + 0{,}17 \times 3{,}55 = 2{,}0835\ [m] \qquad (2.23)$$

I choose the next parameters:

Cabin height is equal: H_{cab} = 2 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. We need to remember that 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 construction amplifications.

Step of normal bulkhead in the fuselage construction is in the range of 360...500mm, depends on the fuselage type and class of passenger saloon.

The windows are placed in one light row. The shape of the window is round, with the diameter of 300...400mm, or rectangular with the rounded corners. The window step corresponds to bulkhead step and is 500...510mm.

For economic salon with the scheme of allocation of seats in the one row (3 + 2) determine the appropriate width of the cabin:

$$B_{cab} = n_2 b_2 + n_3 b_3 + n_n b_n + 2 + \delta + 2\delta = 3{,}130 \text{ [m]} \quad (2.24)$$

The lenghts of the cabin is equal:

$$L_{cab} = L_1 + (N - 1) + L_{cr} + L_2 = 14 \ [m] \quad (2.25)$$

1.3.3 Galleys and buffets

International standards provide that if the plane made a mixed layout, be sure to make two dishes. If flight duration less than 3 hours at this time of food to passengers not issued in this case provided cupboards for water and tea. Tickets to the flight time less than one hour buffets and toilets can not be done. Kitchen cupboards and must be placed at the door, preferably between the cockpit and passenger or cargo have separate doors. Refreshment and food can not be placed near the toilet facilities or connect with wardrobe.

Volume of buffets(galleys) is equal:

$$V_{galley} = 01 \times 90 = 9 \ [m^3] \quad (2.28)$$

Area of buffets(galleys) is equal:

$$S_{galley} = \frac{V_{galley}}{H_{cab}} = \frac{9}{2} = 4{,}5 \ [m^3] \quad (2.29)$$

Number of meals per passenger breakfast, lunch and dinner – 0,8 kg; tea and water – 0,4 kg; If food organized once it is given a set number 1 weighing 0,62 kg. Food passangers appears every 3.5…4 hour flight.

Buffet design similar to prototype.

1.3.4 Layout and calculation of basic parameters of tail unit

One of the most important tasks of the aerodynamic layout is the choice of tail unit placing. For ensuring longitudinal stability during overloading 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.

$$m_x^{Cy} = \bar{x}_T - \bar{x}_F < 0 \qquad (2.32)$$

Where $m^{Cy}{}_x$ –is the moment coefficient; $x_{T.}$ x_F- center of gravity and focus coordinates. If $m^{Cy}{}_x$=0, than the plane has the neutral longitudinal static stability, if $m^{Cy}{}_x$>0, than the plane is statically instable. In the normal aircraft scheme (tail unit is behind the wing), focus of the combination wing – fuselage during the install of the tail unit of moved back.

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

Determination of the tail unit geometrical parameters

Area of vertical tail unit is equal:

$$S_{VTU} = (0{,}18 \ldots 0{,}25)S_w = \ 20\ [m^2] \qquad (2.33)$$

Area o horizontal tail unit is equal:

$$S_{HTU} = (0{,}12 \ldots 0{,}2)S_w = \ 14{,}1\ [m^2] \qquad (2.34)$$

Values L_{htu} and L_{vtu} depend on some factors. First of all, their value are influenced by: the length of he nose part and tail part of the fuselage, sweptback and wing location, and also from the conditions of stability and control of the airplane.

Determination of the elevator area and direction:

Altitude elevator area:

$$S_{el} = (0{,}3 \dots 0{,}4)S_{HTU} = 0{,}35 \times 14{,}1 = 4{,}935\ [m^2] \quad (2.35)$$

Rudder area:

$$S_{rud} = (0{,}35 \dots 0{,}45)S_{VTU} = 0{,}4 \times 20 = 8\ [m^2] \quad (2.36)$$

I Choose the area of aerodynamic balance.

$$If,\ M \geq 0{,}75\text{ , so } S_{el} \approx S_{rud} = (0{,}18 \dots 0{,}23)\ S \quad (2.37)$$

Elevator balance area is equal:

$$S_{el} = S_{EL} * 0{,}2 = 0{,}2 * 8 = 1{,}6\ [m^2] \quad (2.38)$$

Rudder balance area is equal:

$$S_{rud} = S_{RUD} * 0{,}2 = 0{,}2 * 4{,}935 = 0{,}987\ [m^2] \quad (2.39)$$

The area of altitude elevator trim tab:

$$S_{te} = S_{EL} * 0{,}1 = 0{,}1 * 4{,}935 = 0{,}4935\ [m^2] \quad (2.40)$$

Area of rudder trim tab is equal:

$$S_{tr} = S_{RUD} * 0{,}05 = 0{,}05 * 8 = 0{,}4\ [m^2] \quad (2.41)$$

Root chord of horizontal stabilizer is:

$$l_{HTU} = (0{,}4\ldots0{,}5)l_w = 28{,}47 * 0{,}4 = 11{,}388 \qquad (2.42)$$

$$b_{oHTU\ ROOT} = \frac{2S_{HTU} \times \eta_{HTU}}{(1+\eta_{HTU}) \times l_{HTU}} = \frac{2 \times 14{,}1 \ \times 2{,}5}{(1+2{,}5) \times 11{,}388} = \frac{70{,}5}{39{,}858} = 1{,}76\ [m] \qquad (2.43)$$

Tip chord of horizontal stabilizer is:

$$b_{0HTU\ TIP} = \frac{b_{oHTU\ ROOT}}{\eta_{HTU}} = \frac{1{,}76}{2{,}5} = 0{,}704\ [m] \qquad (2.44)$$

Root chord of vertical stabilizer is:

$$b_{oHTU\ ROOT} = \frac{2S_{VTU} \times \eta_{VTU}}{(1+\eta_{VTU}) \times l_{VTU}} = \frac{2 \times 20 \ \times 3}{(1+1) \times 11{,}388} = \frac{120}{45{,}6} = 5{,}2\ [m] \qquad (2.45)$$

Tip chord of vertical stabilizer is:

$$b_{0VTU\ TIP} = \frac{b_{oVTU\ ROOT}}{\eta_{VTU}} = \frac{5{,}2}{3} = 1{,}75\ [m] \qquad (2.46)$$

1.3.5 Choice and description of power plant

Д-436-148 - The Progress D-436 is a three-shaft high by-pass turbofan engine.

Table 2.2 – Examples of application Д-436-148

Model	Thrust	Bypass ratio	Dry weight
Д436-148	15,000 lb_f (66,7 kN)	9	1400

It was initially developed to meet the requirements for late versions of the Yakovlev Yak-42 and the Antonov An-72 in the 1980s. The engine first ran in 1985 and was subsequently certified in 1987. Several variants have been developed and are currently in service with a variety of aircraft.

1.3.6 Wing geometry calculation

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

Full wing area with extensions is:

$$S_{wfull} = \frac{m_0 * g}{p_0} = \frac{41062*9.8}{4564} = 88{,}16\ [m^2] \tag{2.1}$$

Relative wing extensions area is 0.1.

Wing area is:

$$S_w = 88{,}16 * 0{,}9 = 79{,}344\ [m^2] \tag{2.2}$$

Wing span is:

$$l = \sqrt{S_w * \lambda} = \sqrt{88{,}16 * 9{,}2} = 28{,}47\ [m] \tag{2.3}$$

Root chord is:

$$b_0 = 5{,}1\ [m] \tag{2.4}$$

Tip chord is:

$$b_t = 1{,}8\ [m] \tag{2.5}$$

Taper Ratio:

$$\eta_w = \frac{b_0}{b_t} = \frac{5,1}{1,8} = 2,8 \qquad (2.6)$$

Maximum wing width is determined in the forehead i-section and by its span it is equal:

$$C_i = \bar{c} \times b_i = 0,13 \times 1,8 = 0,234\ [m] \qquad (2.7)$$

On board chord for trapezoidal shaped wing is:

$$b_{ob} = b_0 \times \left(1 - \frac{(\eta_w - 1) \times D_f}{\eta_w \times l_w}\right) = 5,2 \times \left(1 - \frac{(2,8 - 1) \times 3,5}{2,8 \times 28,47}\right) = 4,789\ [m] \qquad (2.8)$$

At a choice of power scheme of the wing we determine quantity of longerons and its position, and the places of wing portioning.

On the modern aircraft we use xenon double – or triple – longeron wing; longeron wing is common to the light sport, sanitary and personal aircrafts. Our aircraft has three longerons.

Realtive postion of longerons in wing by chord:

$$\bar{x}_i = \frac{x_i}{b} \qquad (2.9)$$

In wing with two longerons $\overline{x_1} = 0,2$; $\overline{x_2} = 0,6$.

I use the geometrical method of mean aerodynamic chord determination (figure 2.1). Mean aerodynamic chord is equal: $b_{MAC} = 3.69\ [m]$

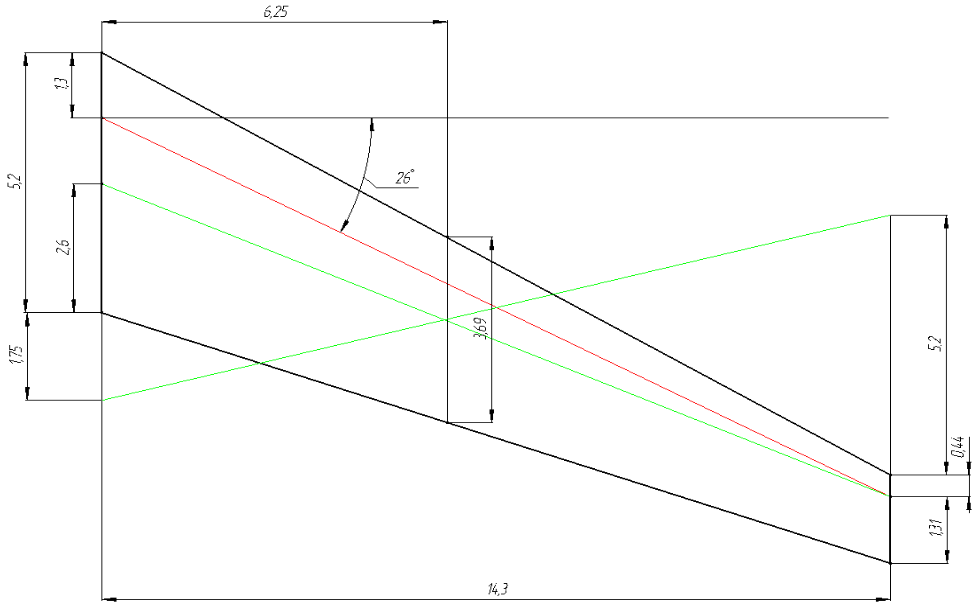

Figure 2.1. – Determination of mean aerodynamic chord

After determination of the geometrical characteristics of the wing we come to the estimation of the ailerons geometrics and high-lift devices.

Ailerons geometrical parameters are determined in next consequence:

Ailerons span:

$$l_{ail} = 0{,}35\ \times \frac{l_w}{2} = \ 0{,}35\ \times \frac{28{,}47}{2} = 4{,}98\ [m] \tag{2.10}$$

Chord of aileron:

$$C_{ail} = 0{,}24\ \times\ b_i = 0{,}24\ \times 1{,}75 = 0{,}42\ [m] \tag{2.11}$$

Aileron area:

$$S_{ail} = 0{,}07\ \times \frac{S_w}{2} = \ 0{,}07\ \times \frac{88{,}16}{2} = 3{,}087\ [m] \tag{2.12}$$

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 xenon decreases.

In the airplanes of the third generation there is a tendency to decrease relative wing span and ailerons area. So, $l_{ail} = 0.122$. 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, which improves take off and landing characteristics of the aircraft.

Aerodynamic compensation of the aileron.

Axial :

$$S_{axinail} \le (0.25\ldots0.28)\, S_{ail} = 0{,}27 \times 3{,}087 = 0{,}833\ [m^2] \tag{2.13}$$

Inner axial compensation

$$S_{inaxinail} = (0.3..0.31)\, S_{ail} = 0{,}3 \times 3{,}087 = 0{,}926\ [m^2] \tag{2.14}$$

Area of ailerons trim tab.

For two engine airplane:

$$S_{tr.ail} = 0{,}05 \times S_{ail} = 0{,}05 \times 3{,}087 = 0{,}15435\ [m^2] \tag{2.15}$$

Range of aileron deflection

Upward $\delta'_{ail} \ge 25$;

Downward $\delta''_{ail} \ge 15^{\circ}$.

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

Before doing following calculations it is necessary to choose the type of airfoil due to the airfoil catalog, specify the value of lift coefficient $C_{y\max bw}$ and determine necessary increase for this coefficient $C_{y\max}$ for the high-lift devices outlet by the formula:

$$\Delta C_{y\max} = (\frac{C_{y\max l}}{C_{y\max bw}}) \tag{2.16}$$

Where $C_{y\max l}$ is necessary coefficient of the lifting force in the landing configuration of the wing by the aircraft landing insuring (it is determined during the choice is the aircraft parameters).

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

b_{sf} = 0.25..0.3 – for the split edge flaps;

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

b_f = 0.3..0.4 – for three slotted flaps and Faylers flaps;

b_s = 0.1...0.15× $b_i = 0.1 \times 1{,}75 = 0{,}175$ – slats.

1.3.7 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:

$$S_{cargo} = \frac{M_{bag}}{0{,}4K} + \frac{M_{cargo\ and\ mail}}{0{,}6K} = \frac{20 \times 90}{0{,}4 \times 600} + \frac{15 \times 90}{0{,}6 \times 100} = 21[m^2] \tag{2.26}$$

Cargo compartment volume is equal:

$$V_{cargo} = v \times n_{pass} = 0{,}2 \times 90 = 16[m^3] \tag{2.27}$$

Luggage compartment design similar to the prototype

1.3.8 Lavatories

Number of toilet facilities is determined by the number of passengers and flight duration: with t> 4:00 one toilet for 40 passengers, at t = 2 ... 4 hours and 50 passenger’s t <2 hours to 60 passengers.

The number of lavatories I choose according to the original airplane and it is equal:

$$n_{lav} = 3 \tag{2.30}$$

Area of lavatory:

$$S_{lav} = 1{,}5[m^3] \tag{2.31}$$

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

1.3.9 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 axel offset is:

$$e = b_{MAC} \times (0{,}15 \dots 0{,}2) = 0{,}2 \times 3{,}69 = 0{,}738\ [m] \tag{2.47}$$

With the large wheel axial offset the lift-of of the front gear during take of is complicated, and with small, the drop of the airplane on the tail is possible, when the loading of the back of the airplane comes first. Landing gear wheel base comes from the expression:

Landing gear wheel base comes from the expression:

$$B = (0{,}3 \dots 0{,}4) L_{\phi} = (6 \dots 10)e \tag{2.48}$$

$$B = (0{,}3 \dots 0{,}4)L_f = (6 \dots 10)e = 0{,}4 \times 29{,}75 = 12\ [m] \tag{2.49}$$

The last equation means that the nose support carries 6...10% of aircraft weight.

Front wheel axial offset will be equal:

$$d_{ng} = B - e = 8{,}18\ [m] \tag{2.50}$$

Wheel track is:

$$T = (0{,}7 \dots 1{,}2)B\ \leq 12\ m = 0{,}7 \times 8{,}9 = 6{,}24 \tag{2.51}$$

I choose this parameter similar to prototype: T = 4,3 [m]

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

Wheels for the landing gear is chosen by the size and run loading on it from the take off weight; for the front support we consider dynamic loading also.

Type of the pneumatics (balloon, half balloon, arched) and the pressure in it is determined by the runway surface, which should be used. We install breaks on the main wheel, and sometimes for the front wheel also.

The load on the wheel is determined:

K_g = 1.5...2.0 – dynamics coefficient.

Nose wheel load is equal:

$$P_{NLG} = \frac{\left(9{,}81 \times e \times k_g \times m_0\right)}{(B \times z)} = \frac{(9{,}81 \times 0{,}738 \times 1{,}5 \times 41000)}{(8{,}925\ \times 2)} = \frac{445256}{17{,}8} = 25014{,}38\ [N] \tag{2.52}$$

Main wheel load is equal:

$$P_{MLG} = \frac{(9{,}81 \times (B - e) \times m_0)}{(B \times z \times n)} = \frac{(9{,}81 \times (8{,}925 - 0{,}738) \times 41000)}{(8{,}925\ \times 4)} = \frac{3290077}{35{,}7} = 92159\ [N] \tag{2.53}$$

Table 2.1 – Aviation tires for designing aircraft

Main gear		Nose gear	
Tire size	Ply rating	Tire size	Ply rating
1100x 420	30	850x325 mm	12

1.4 Aircraft center of gravity position determination

1.4.1 Determination of the centering of the equipped fuselage:

Origin of the coordinates is chosen in the projection of the nose of the fuselage on the horizontal axis. For the axis X the construction part of the fuselage is given. The example list of the objects for the AC, which engines are mounted under the wing, is given in table 2.4.

The CG coordinates of the FEF are determined by formulas:

$$X_f = \frac{\sum m_i^` X_i^`}{\sum m_i^`}; XY_f = \frac{\sum m_i^` Y_i^`}{\sum m_i^`} \quad (2.50)$$

We can find fuselage center of gravity coordinate X_f by divided sum of mass moment of the fuselage (m_i', X_i) on sum of total mass of fuselage (m_i'):

$$X_f = \sum m_i \times X_i / \sum m_i = 23{,}553 \quad (2.55)$$

AC fuselage centering of gravity masses drawing which is presented in Appendix B.

After we determined the center of gravity (CG of FEW) and fuselage, we construct the moment equilibrium equation relatively fuselage nose:

$$m_f \times x_f + m_w \times (x_{MAC} + x'_w) = m_0 \times (x_{MAC} + C) \quad (2.56)$$

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

$$X_{MAC} = \frac{m_f \times x_f + m_w x_w - m_0 \times c_n}{m_0 - m_w} = 22{,}502 \quad (2.57)$$

Where m_0 – AC takeoff mass, kg; m_f – mass of FEF, kg; m_w – mass of FEW, kg; C – distance from MAC leading edge to the CG point, determined by the designer.

Table 2.4 – Trim sheet of equipped fuselage masses

1	2	3		4	5
№	Objects	Mass		Coordinates of C.G. (m)	Moment (kgm)
		Units	Total (kg)		
1	Fuselage	0,117	4841,6	14,85	71898,063
2	Horizontal tail unit	0,0142	583,4	29	16921,239
3	Vertical tail unit	0,0159	655,3	27,5	18022,111
4	Radar equipment	0,0035	143,7	1	143,717
5	Instrument panel	0,0061	250,4	5	1252,391
6	Air-navigation system	0,0052	213,5	3	640,567
7	Radio equipment	0,0026	106,7	3	320,283
8	Toilet 1	0,00146	60,2	4,5	271,014
9	Toilet 2 and 3	0,00293	120,4	19,5	2348,722
10	Cargo compartment equipment	0,003	123,1	14,85	1829,312
11	Buffet 1	0,00146	60,2	4	240,901
12	Buffet 2	0,00293	120,4	20	2408,946
13	Control system, 70%	0,0056	229,9	14,85	3414,715
14	Electrical equipment, 70%	0,0304	1249,1	14,85	18549,224
15	Hydraulic system, 30%	0,00618	253,7	20,3	5151,3921
16	Air conditioning system equipment	0,00711	291,9	14,85	4335,4696
17	Decorative paneling	0,0051	209,4	14,85	3109,830
18	Heat and sound isolation	0,0051	209,4	14,85	3109,830
19	Oxygen equipment	0,000675	27,7	14,85	411,642
20	Anti-icing system, 50%	0,0118	486,5	23	11288,765

Ending of table 2.4 – Trim sheet of equipped fuselage masses

1	2	3		4	5
21	Tools	0,0061	250,4	4	1001,91
21	Pass. cabin add. equipment	0,00215	88,6	19	1683,504
22	Seats of passengers	0,0125	515,2	17,5	9017,043
23	Rescue equipment	0,00251	103,4	19	1965,069
24	Seats of crew	0,000271	11,1	2,8	31,246
25	Seat of attendants 1	9,70611E-05	3,9	4	15,942
26	Seat of attendants 2	0,000194122	3,9	24	191,305
27	Auxiliary power unit	0,0034	139,6	25	3490,27
28	Equiped fuselage without comercial loads	0,300	12357,8	16,6	205064,435
29	Passangers of economical class 1	0,153	6300	17,5	110250
30	Food 1	0,00053	21,9	4	87,681
31	Food 2 and 3	0,00106	43,8	20	876,814
32	Baggage of passanger	0,043	2050	18	36900
33	Cargo	0,01533	630	14,85	9355,5
34	Crew	0,00340	140	2,8	392
35	Attendants 1 and 2	0,00340	140	4	560
36	Attendants 3	0,00170	70	24	1680
37	Other service equipment and mail	0,00511	210,2	25	5255,821
38	Non-typical equipment	0	0	25	0
	Total	0,534	21963,8	16,865	370422,253

1.4.2 Determination of centering 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, mass themselves and their center of gravity coordinates. The origin of the given coordinates of the mass centers is chosen by the projection of the nose point of the mean aerodynamic chord (MAC) for the surface XOY. The positive meanings of the coordinates of the mass centers are accepted for the end part of the aircraft.

The example list of the mass objects for the aircraft, where the engines are located under the wing, included the names given in the table 2.3.

The example list of the mass objects for the aircraft, where the engines are located in the wing, included the names given in the table 2.3. The mass of AC is 91295 kg.

Coordinates of the center of power for the equipped wing are defined by the formulas:

Table 2.3 - Trim sheet of equipped wing masses

1	2	3		4	5
No	Name	Mass		C.G. coordinates (m)	Moment (kgm)
		Units	total (kg)		
1	Wing (structure)	0,11713	4809,5	0,54	7453,90
2	Fuel system, 1000%	0,0056	229,9	0,54	356,37
3	Control system, 30%	0,0024	98,5	0,8	218,18
4	Electrical equip. 10%	0,00338	138,7	0,3	51,21
5	Anti-icing system 50%	0,01185	486,5	0,3	179,54
6	Hydraulic system, 70%	0,01442	592,1	0,8	1310,94
7	Power units	0,09654	2964	-3	-8892

Ending of table 2.3 - Trim sheet of equipped wing masses

1	2	3	4	5	6
9	Equiped wing without below	0,25132	9319,5	0,07	678,16
10	Nose landing gear 15%	0,0063345	260,10	-9	-2340,96
11	Main landing gear 85%	0,0358955	1473,94	3	4421,82
12	Fuel	0,19557	8030,49	0,54	12741,98
13	Equiped wing	0,48912	19084,11	0,81	15501,01

1.4.3 Calculation of center of gravity positioning variants

The list of mass objects for centre of gravity variant calculation given in Table 2.5 and Center of gravity calculation options given in table 2.6, completes on the base of both previous tables. Origin of the coordinates is chosen in the projection of the nose of the fuselage on the horizontal axis. After designing of the wing and the fuselage we have made the calculations of the center of gravity determination of the equipped aircraft.

Table 2.5 – Calculation of C.G. positioning variants

Name Object	Mass, kg m_i	Coordinates C.G. m	Moment kgm
Equiped wing without fuel and L.G.	9319,5	13,9	129851,568
Nose landing gear (retracted)	260,1	2	260,107
Main landing gear (retracted)	1473,9	14	20635,174
Fuel	8030,4	14,6	117138,426
Equiped fuselage	12357,8	16,6	205064,435
Passangers of economical class 1	6300	14,8	93555
Food 1	21,9	4,5	98,641
Food 2	43,8	24	1052,177
Baggage of passanger 1	1800	14,6	26280
Cargo	630	14,6	9198
Crew	140	2,8	392
Attendants 1	140	4	560
Attendants 2	70	19,5	1365
Nose landing gear (opened)	260,1	3	520,214
Main landing gear (opened)	1473,9	14	20635,17

Table 2.6 – Airplanes C.G. position variants

№п/п	Name of objects	Mass, kg	Momen, kgm	C.G. m	Centering %
1	Take-off mass (L.G. opened)	40587,7	605450,530	14,9	26,663
2	Take-off mass (L.G. retracted)	40587,7	605710,638	14,9	26,836
3	Landing variant (L.G. opened)	39721,8	592627,871	14,9	26,727
4	Transportation variant (without payload)	31791,9	475526,818	14,9	27,757
5	Parking variant (without fuel and payload)	23411,4	356071,3921	15,2	34,581

Conclusion to the part 1

We analyzed the prototypes for the task. The main characteristics of the design were selected and all the main components of the aircraft were described. Maximum passanger capacity equal 90 passangers.

Also made a selection of the engines that meet the requirements for the projected aircraft thrust 67 kH and determined the preliminary geometric and structural parameters of the fuselage layout.

In this part we have determined the center mass position characteristics. We have showed the main calculations of an aircraft. We have also checked the mass position of the main parts of the aircraft and main eguipment and furnishing by its distance from the main aerodynamic chord. After designing of the wing and the fuselage we have made the calculations of the center of gravity determination of the equipped aircraft.

PART 2

2.1 Strength calculation of the lever

2.1.1 General description of handrail and struts Z0

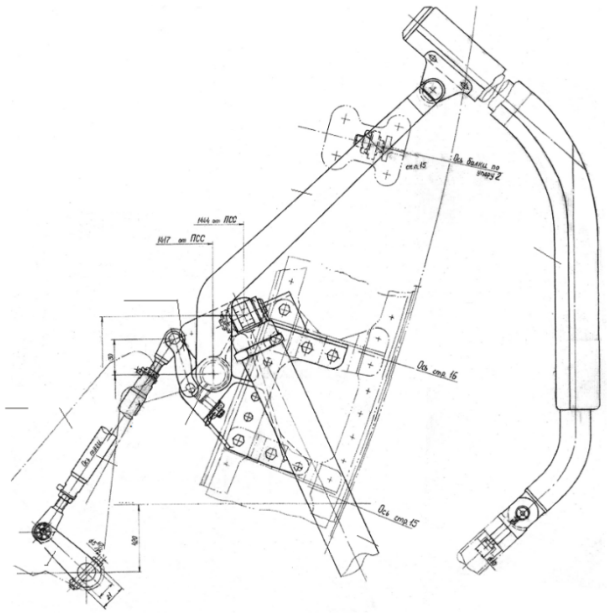

Fig.2.1. View against a flight. The position of the strut Z1, handrail Z2 and lever Z3 with the entrance door open.

Figures 1 and 2. show the position of the strut Z1, the handrail Z2 and the lever Z3 with the entrance door open. In the open position, the airstair is helded by two struts, which carry the load from the passengers during loading - unloading. Structures consist of two components: - a strut Z1 (visually viewed) attached to the fuselage and its continuation (hidden under the composition part of the airstair) and mounted on the wall of the crossbeam No.4 of the tailgate.

The handrail is mounted on the rear side of the airstair. The handrail is connected with a lever, having a mount with a bracket, that is mounted on the fuselage. At loading the handrail down along its plane of displacement, - the lever rests at the abutment on the wall.

At the initial moment of raising the airstair formed telescopic struts. The rocking chair, fixed on the axis of the drive, turns and pulls the thrust, which turns the rocking chair, attached to the bracket on the fuselage (see. Fig. 1).

The rocking chair has an oval outer contour which draws the “cheeks” of the braker ring.

When the front door is open, the brake ring clamps the axis belonging to the lever, which prevents the handrail from moving upwards along its pickup plane.

Loads:

Calculation case 1. «Front door open. – At each step of the ramp there is a person.

Calculated load on a step from a person:

$$P_{у}^{P} = P_{man}^{Э} \times f_{saf} = 77 \times 2{,}0 = 154\ [kg] \tag{3.1}$$

Estimated force from the weight of the door-ladder:

$$P_{door}^{P} = G_{door}^{Э} \times f_{saf} = 72 \times 2{,}0 = 144\ [kg] \tag{3.2}$$

Calculation case 2. Front door open.

Calculated load applied to the handrail from a person:

$$P_{handhold}^{P} = P_{handhold}^{Э} \times f_{saf} = 50 \times 2{,}0 = 100\ [kg] \tag{3.3}$$

The load is applied to the upper contour of the rail at any point.

The load direction is determined by the operating conditions.

(See "Recommendations for the standards of the strength of movable ground maintenance stuff for aircraft").

2.1. Effort is applied to the upper contour of the rail at any point and in the plane of the layout (rotation). The direction of force application - in the bottom along the axis of the pipe handrail.

2.2. Effort is applied to the upper contour of the handrail at the point of attachment of the lever. The direction of the force is perpendicular to the plane of the handrail layout (rotation).

2.2.1. The direction of the force is inside the doorway.

2.2.2. The direction of the force is outside the doorway.

Calculation case 3. Front door open.

Effort is applied by the hand of a person to the upper contour of the handrail at any point and in the plane of the layout (rotation). The direction of the force is up along the axis of the handrail tube.

The calculated force from the hand of a person according to 25.405 CS-25:

$$P^P = \frac{1 + 0{,}39R}{3} \times 22 = \frac{1 + 0{,}39 \times 30{,}7}{3} = 68\ [kg] \quad (3.4)$$

Calculation case 1. +2.2. Front door open.

1.+2.2.1 - The combined effect of the load of calculated cases.

1.+2.2.2 - The combined effect of the load of calculated cases.

3.1.2 Define the calculated forces acting in the struts.

Calculation case 1. The front entrance door is open. At each step of the ramp a person.

Calculated load on a step from a person

$$P_Y^P = P_{man}^E \times f_{saf} = 77 \times 2{,}0 = 154\ [kg] \quad (3.5)$$

Rated force on two struts:

$$\sum P_{strut}^P = \frac{P_У^Э \times (l_1 + l_2 + l_3 + l_4 + l_5 + l_6)}{H_{strut}} = \quad (3.6)$$

$$= \frac{154 \times (27 + 50 + 75 + 100 + 122 + 145)}{38} = 2100\ [kg]$$

Estimated force per strut:

$$P^{P}_{strut} = \frac{P^{P}_{strut}}{n} = \frac{2100}{2} = 1050[\text{kg}] \tag{3.7}$$

Lever arm

Stamping material 1933T3   OCT1 90073-85

б = 4500 [kg/sm^2]

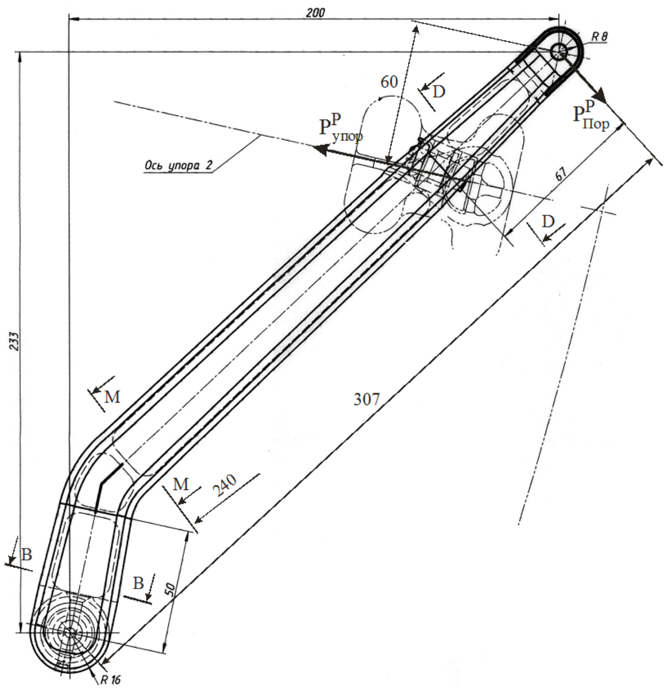

Fig.3.3. Position of the lever with the door open.

Determine the force acting on the support (screw x):

Calculation case. 2.1.

$$P^{P}_{detent} = \frac{P^{P}_{handhold} \times l_{lever}}{l_{detent}} = \frac{100 \times 30{,}7}{30{,}7 - 6{,}0} = 125\ [kg] \tag{3.8}$$

Eye calculation:

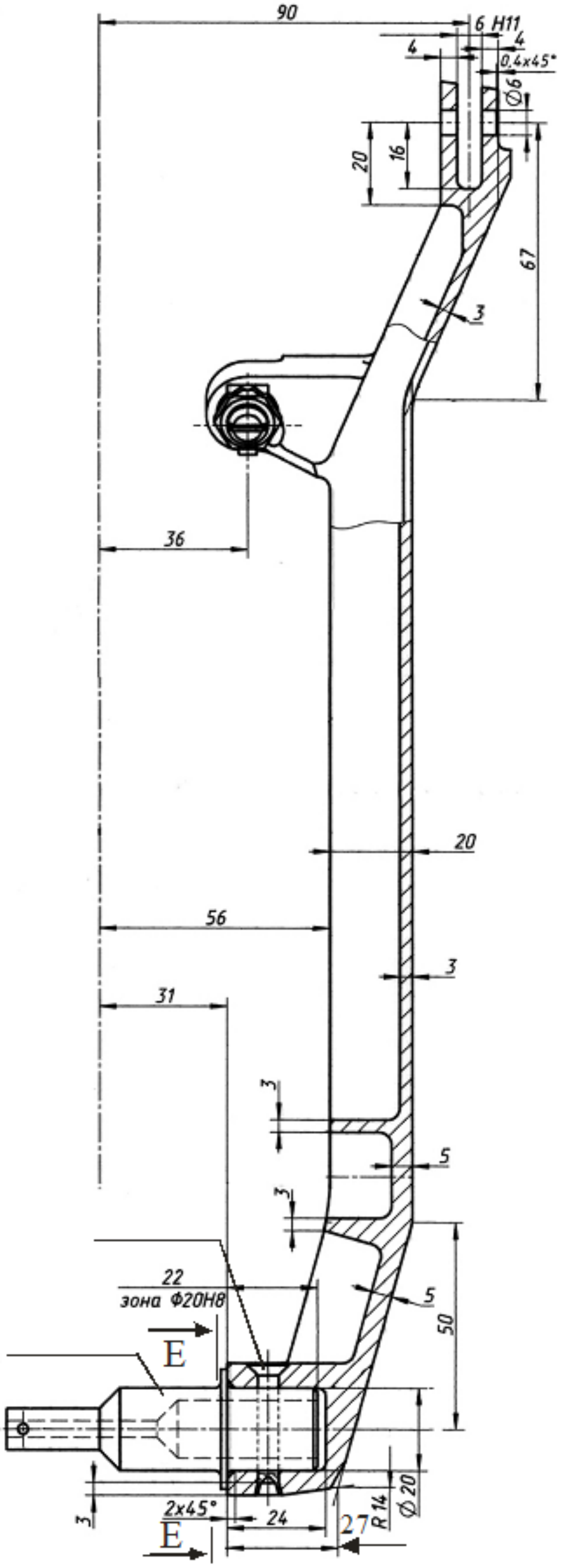

Fig.3.4. Lever cross-section

Calculation case 2.1.

Rupture:

$$P^P_{rupture} = 0{,}85 \times k \times \sigma_b \times 2 \times (R - r) \times \delta = \tag{3.9}$$

$$= 0{,}85 \times 0{,}9 \times 4500 \times 2(0{,}8 - 0{,}3) \times 2 \times 0{,}4 = 2750\ [kg]$$

Where $\kappa = 0{,}9$ at $\sigma_b < 10000\ {}^{kg}/_{cm^2}$

$$\eta_{rupt} = \frac{P^P_{rupt}}{P^P_{hh}} = \frac{2750}{100} > 2{,}0 \tag{3.10}$$

Shear:

$$P^P_{shear} = 0{,}4 \times \sigma_b \times 2 \times \sqrt{R^2 - r^2} \times \delta = \tag{3.11}$$

$$= 0{,}4 \times 4500 \times 2 \times \sqrt{0{,}8^2 \times 0{,}3^2} \times (0{,}4 + 0{,}36) = 2020\ [kg]$$

$$\eta_{shear} = \frac{P^P_{shear}}{P^P_{hh}} = \frac{2020}{100} > 2{,}0 \tag{3.12}$$

Compression:

$$P^P_{comp} = k_1 \times d \times (\delta - f) \times \sigma_b = 0{,}4 \times 0{,}6 \times 4500 \times (0{,}4 + 0{,}36) = 820\ [kg] \tag{3.13}$$

$$\eta_{comp} = \frac{P^P_{comp}}{P^P_{hh}} = \frac{820}{100} > 2{,}0 \tag{3.14}$$

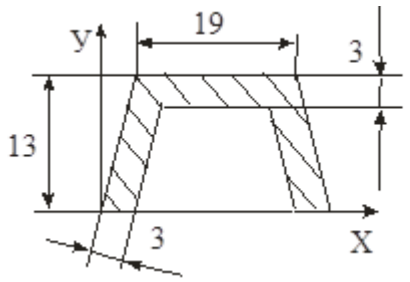

Fig.3.5. Cross-section D-D

Geometrical characteristics:

$F = 1{,}17\ [cm^2]$

$У_{ц.т} = 0{,}82\ (0{,}48)\ [cm]$

$I_X = 0{,}178\ [cm^4]$

$W_{X1} = 0{,}218\ [cm^3]$

$W_{X2} = 0{,}368\ [cm^3]$

$X_{ц.т} = 0{,}95\ [cm]$

$I_X = 0{,}56\ [cm^4]$

$W_{у1} = W_{у2} = 0{,}59\ [cm^3]$

$$I_{КР} = \frac{\eta}{3} \times (2 \times b_{1,2} \times \delta^3 + b_3 \times \delta_3 = \frac{1{,}12}{3} \times (2 \times 1{,}3 \times 0{,}3^3 + 2{,}0 \times 0{,}3^3) = 0{,}0464\ [cm^4] \quad (3.15)$$

Critical stress for local buckling of the shelf:

$$\sigma_{KP}^{P} = f\left(\frac{b}{\delta}; \xi\right) = -4000\ [\frac{kg}{cm^2}] \quad (3.16)$$

Where $\frac{b}{\delta} = \frac{1}{0{,}3} = 3{,}33\ ; \xi = \frac{\delta}{\delta_1}^3 \times \frac{b_1}{b} = \left(\frac{0{,}3}{0{,}3}\right)^3 \times \frac{1{,}3}{1} > 1$

Calculation case 2.1. The direction of the force - down and in the plane of the layout (rotation) of the handrail.

Bending moment in cross section D - D:

$$M_{D-D}^{P} = P_{hh}^{P} \times l_{D-D} = 100 \times 5{,}5 = 550\ [kg \times cm] \tag{3.17}$$

Sectional stresses:

$$\sigma_{1,2}^{P} = \frac{M_{bend.\ D-D}^{P}}{W_{y1,2}} = \frac{550}{0{,}59} = \pm 930\ [{}^{kg}/_{cm^2}] \tag{3.18}$$

Torsion moment in section D - D:

$$M_{KP}^{P} = P_{hh}^{P} \times h_{D-D} = 100 \times 1 = 100\ [kg \times cm] \tag{3.19}$$

_Tangential stress acting in cross section:

$$\tau^{P} = \frac{M_{KP}^{P} \times \delta}{I_{kp}} = \frac{100 \times 0{,}3}{0{,}0464} = 650\ [\frac{kg}{cm^2}] \tag{3.20}$$

$$\sigma_{\text{Экв}}^{P} = \sqrt{\left(\sigma_{1,2}^{P}\right) + 3\tau_{D-D}^{P}} = \sqrt{930^2 + 3 \times 650^2} = 1460\ [{}^{kg}/_{cm^2}] \tag{3.21}$$

$$\eta_{\text{Экв}} = \frac{\sigma_B}{\sigma_{\text{Экв}}^{P}} = \frac{4500}{1460} > 2{,}0 \tag{3.22}$$

Calculation case 2.2. The direction of the force - perpendicular to the plane of the layout (rotation) of the handrail.

Bending moment in cross section D - D:

$$M_{D-D}^{P} = P_{hh}^{P} \times l_{D-D} = 100 \times 5{,}5 = 550\ [kg \times cm] \tag{3.23}$$

Sectional stresses:

$$\sigma_{1,2}^{P} = \frac{M_{bend.\ D-D}^{P}}{W_{X1}} = \frac{550}{0,218} = \pm 2520\ [{}^{kg}/_{cm^2}] \tag{3.24}$$

$$\eta = \frac{\sigma_{KP}}{\sigma_{1,2}^{P}} = \frac{4000}{2520} = 1,6 \tag{3.25}$$

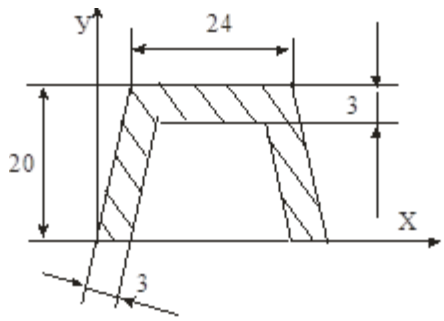

Fig.3.5. Cross-section M-M

Geometrical characteristics

$F = 1,91\ [cm^2]$

$У_{ц.т} = 1,23\ (0,77)\ [m]$

$I_X = 0,74\ [cm^4]$

$W_{X1} = 0,604\ [cm^3]$

$W_{X2} = 0,958\ [cm^3]$

$X_{п.т} = 1,2\ [cm]$

$I_X = 1,47\ [cm^4]$

$W_{у2} = W_{у2} = 1,23\ [cm^3]$

$$I_{KP} = \frac{\eta}{3} \times (2 \times b_{1,2} \times \delta^3 + b_3 \times \delta_3 = \frac{1,12}{3} \times (2 \times 2 \times 0,3^3 + 2,4 \times 0,3^3) = 0,064\ [cm^4] \tag{3.26}$$

Critical stress of local buckling of the shelf:

$$\sigma^P_{KP} = f\left(\frac{b}{\delta}; \xi\right) = -4150\ [\frac{kg}{cm^2}] \tag{3.27}$$

where $\frac{b}{\delta} = \frac{1,7}{0,3} = 5,6$; $\xi = \left(\frac{\delta}{\delta_1}\right)^3 \times \frac{b_1}{b} = \left(\frac{0,3}{0,3}\right)^3 \times \frac{1,8}{1,7} > 1$

Calculation case 3. The direction of force from the hand of man - up and in the plane of the layout (rotation) of the handrail.

$$P^P = 68\ [kg] \tag{3.28}$$

Bending moment in cross section M – M (see. fig. 3):

$$M^P_{M-M} = P^P_{hh} \times l_{M-M} = 68 \times 24 = 1630\ [kg \times cm] \tag{3.29}$$

Sectional stresses:

$$\sigma^P_{1,2} = \frac{M^P_{bend.\ M-M}}{W_{y1,2}} = \frac{1630}{1,23} = \pm 1330\ [{}^{kg}/_{cm^2}] \tag{3.30}$$

Torsion moment in section M - M:

$$M^P_{KP} = P^P_{hh} \times h_{D-D} = 68 \times 1,4 = 95,2\ \ [kg \times cm] \tag{3.31}$$

Shear stresses acting in cross section:

$$\tau^P_{M-M} = \frac{M^P_{KP} \times \delta}{I_{kp}} = \frac{95,2 \times 0,3}{0,064} = 450\ [\frac{kg}{cm^2}] \tag{3.32}$$

$$\sigma^P_{\text{Экв}} = \sqrt{\left(\sigma^P_{1,2}\right) + 3\tau^P_{D-D}} = \sqrt{1330^2 + 3 \times 450^2} = 1540\ [{}^{kg}/_{cm^2}] \quad (3.33)$$

$$\eta_{\text{Экв}} = \frac{\sigma_B}{\sigma^P_{\text{Экв}}} = \frac{4500}{1560} > 2{,}0 \quad (3.34)$$

Calculation case 2.2 The direction of the force is perpendicular to the plane of the handrail layout (rotation).

Bending moment in cross section M - M:

$$M^P_{M-M} = P^P_{hh} \times l_{M-M} = 100 \times 23{,}5 = 2350\ [kg \times cm] \quad (3.35)$$

Sectional stresses:

$$\sigma^P_{1,2} = \frac{M^P_{bend.\ M-M}}{W_1} = \frac{2350}{0{,}604} = \pm 3890\ [{}^{kg}/_{cm^2}] \quad (3.36)$$

$$\eta_{\text{Экв}} = \frac{\sigma_{KP}}{\sigma^P_{1,2}} = \frac{4150}{3890} = 1{,}07 \quad (3.37)$$

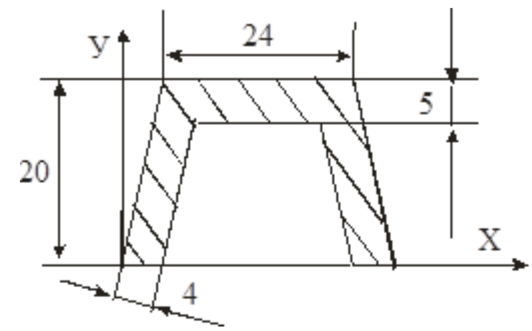

Fig.3.6. Cross-section B-B

Geometrical characteristic

$F = 2{,}55\ [cm^2]$

$У_{ц.т} = 1{,}22\ (0{,}78)\ [m]$

$I_X = 0{,}91\ [cm^4]$

$W_{X1} = 0{,}75\ [cm^3]$

$W_{X2} = 1{,}17\ [cm^3]$

$X_{п.т} = 1{,}2\ [cm]$

$I_X = 1{,}8\ [cm^4]$

$W_{y2} = W_{y2} = 1{,}5\ [cm^3]$

$$I_{КР} = \frac{\eta}{3} \times (2 \times b_{1,2} \times \delta^3 + b_3 \times \delta_3 = \frac{1{,}12}{3} \times (2 \times 2{,}0 \times 0{,}4^3 + 2{,}4 \times 0{,}5^3) = 0{,}2\ [cm^4] \quad (3.38)$$

Critical stress of local buckling of the shelf:

$$\sigma_{KP}^{P} = f\left(\frac{b}{\delta}; \xi\right) = -4300\ [\frac{kg}{cm^2}] \quad (3.39)$$

where $\frac{b}{\delta} = \frac{1{,}5}{0{,}4} = 3{,}75$; $\xi = \left(\frac{\delta}{\delta_1}\right)^3 \times \frac{b_1}{b} = \left(\frac{0{,}4}{0{,}5}\right)^3 \times \frac{2{,}4}{1{,}5} = 0{,}82$

Calculation case 3. The direction of the force - up and in the plane of the layout (rotation) of the handrail.

Bending moment in cross section B - B:

$$M_{B-B}^{P} = P_{hh}^{P} \times l_{B-B} = 68 \times 29 = 1972\ [kg \times cm] \quad (3.40)$$

Sectional stresses:

$$\sigma_{1,2}^{P} = \frac{M_{bend.\ B-B}^{P}}{W_{y1,2}} = \frac{1972}{1{,}5} = \pm 1315\ [{}^{kg}/{}_{cm^2}] \quad (3.41)$$

Torsion moment in section B - B:

$$M_{KP}^{P} = P_{hh}^{P} \times h_{B-B} = 68 \times 1{,}8 = 125 \ \ [kg \times cm] \tag{3.42}$$

Shear stresses acting in cross section:

$$\tau_{B-B}^{P} = \frac{M_{KP}^{P} \times \delta}{I_{kp}} = \frac{125 \times 0{,}4}{0{,}2} = 250 \ [\frac{kg}{cm^2}] \tag{3.43}$$

$$\sigma_{\text{Экв}}^{P} = \sqrt{(\sigma_{1,2}^{P}) + 3\tau_{B-B}^{P}} = \sqrt{1315^2 + 3 \times 250^2} = 1385 \ [{}^{kg}/{}_{cm^2}] \tag{3.44}$$

$$\eta_{\text{Экв}} = \frac{\sigma_B}{\sigma_{\text{Экв}}^{P}} = \frac{4500}{1385} > 2{,}0 \tag{3.45}$$

The lever is attached to axle by axle of ∅5 from 20X13 (with an axial flare in the hole in the lever).

Breaking force of the smooth part of the axis:

$$P_{shear}^{P} = \frac{P_{Cp.30\,\text{ХГСА}}^{P} \times \sigma_B^{20X13}}{\sigma_B^{30\,\text{ХГСА}}} = \frac{1480 \times 8500}{11000} = 1060 \ [kg] \tag{3.46}$$

Effort on one plane of a cut of a smooth part of an axis:

$$P_{axis\ c-s}^{P} = \frac{M_{\text{кр}}^{P}}{D} = \frac{68 \times 30{,}7}{2{,}0} = 1045 \ [kg] \tag{3.47}$$

$$\eta_{shear} = \frac{P_{shear}^{P}}{P_{axis\ c-s}^{P}} = \frac{1060}{1045} = 1{,}014 \tag{3.48}$$

Destroying efforts of crushing the wall of the lever under the axis:

$$P_{comp}^{P} = 1{,}3 \times \sigma_b \times d \times \delta = 1{,}3 \ \times 4500 \times 0{,}5 \times 0{,}6 = 1755\ [kg] \qquad 3.(49)$$

$$\eta_{comp} = \frac{P_{comp}^{P}}{P_{axis\ c-s}^{P}} = \frac{1755}{1045} = 1{,}68 \qquad (3.50)$$

Calculation case 2.2 The direction of the force - perpendicular to the plane of the layout (rotation) of the handrail.

Bending moment in cross section B - B:

$$M_{B-B}^{P} = P_{hh}^{P} \times l_{B-B} = 100 \times 29 = 2900\ [kg \times cm] \qquad (3.51)$$

Sectional stresses:

$$\sigma_{1,2}^{P} = \frac{M_{bend.\ B-B}^{P}}{W_1} = \frac{2900}{0{,}75} = \pm 3865\ [{}^{kg}/{}_{cm^2}] \qquad (3.52)$$

$$\eta_{\text{экв}} = \frac{\sigma_{KP}}{\sigma_{1,2}^{P}} = \frac{4300}{3865} = 1{,}11 \qquad (3.53)$$

Axis

Material 07Х16Н6-ш, ТУ14-1-16060-76

б = 11000 [kg/sm^2]

Calculation case 3. The direction of the force of the human hand - up and in the plane of the layout (rotation) of the handrail.

The lever is attached to axle by axle of ∅5 from 20Х13 (with an axial flare in the hole in the lever).

Destroying efforts of crushing the axis of the wall under the axis:

$$P_{comp}^{P} = 1{,}3 \times \sigma_b \times d_O \times \delta = 1{,}3 \times 8500 \times 0{,}5 \times \frac{(2{,}0 - 1{,}4)}{2} = 1655\ [kg] \quad (3.54)$$

$$\eta_{comp} = \frac{P_{comp}^{P}}{P_{axis\ c-s}^{P}} = \frac{1655}{1045} = 1{,}58 \quad (3.55)$$

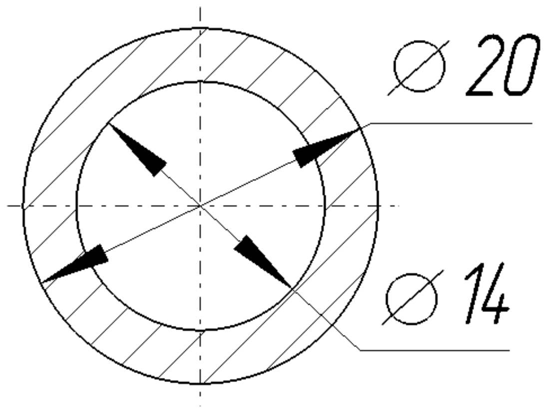

Fig.3.7. Cross-section E-E

Geometrical characteristics:

$$F = \frac{\pi}{4} \times (D^2 - d^2) = \frac{3{,}14}{4} \times (2{,}0^2 - 1{,}4^2) = 1{,}622\ [cm^2] \quad (3.56)$$

$$I_X = \frac{\pi}{64} \times (D^4 - d^4) = \frac{3{,}14}{64} \times (2{,}0^4 - 1{,}4^4) = 0{,}597\ [cm^4] \quad (3.57)$$

$$I_{kp} = \frac{\pi}{32} \times (D^4 - d^4) = \frac{3{,}14}{32} \times (2{,}0^4 - 1{,}4^4) = 1{,}194\ [cm^4] \quad (3.57)$$

$$W_X = \frac{\pi}{32} \times \frac{(D^4 - d^4)}{D} = \frac{3{,}14}{32} \times \frac{(2{,}0^4 - 1{,}4^4)}{2{,}0} = 0{,}597\ [cm^3] \quad (3.58)$$

$$W_{kp} = \frac{\pi}{16} \times \frac{(D^4 - d^4)}{D} = \frac{3{,}14}{16} \times \frac{(2{,}0^4 - 1{,}4^4)}{2{,}0} = 1{,}194\ [cm^3] \quad (3.59)$$

Torsion moment in section E - E:

$$M_{KP}^{P} = P_{hh}^{P} \times l_{lever} = 68 \times 30{,}7 = 2090\ [kg \times cm] \tag{3.60}$$

Shear stresses acting in cross section:

$$\tau_{axis}^{P} = \frac{M_{KP}^{P}}{W_{kp}} = \frac{2090}{1{,}194} = 1750\ [\frac{kg}{cm^2}] \tag{3.61}$$

Torsional stresses:

$$\tau_{kp}^{P} = f\left(\frac{D}{\delta};\frac{l}{D}\right) = 6000\ [\frac{kg}{cm^2}] \tag{3.62}$$

where: $\frac{D}{\delta} = \frac{2{,}0}{0{,}3} = 6{,}66$; $\frac{l}{D} = \frac{2{,}0}{2{,}0} = 1{,}0$;

(See. Static Strength Reference 000.00.0000.003 МП-74)

$$\eta_{axis} = \frac{\tau_{kp}^{P}}{\tau_{axis}^{P}} = \frac{6000}{2570} > 2 \tag{3.63}$$

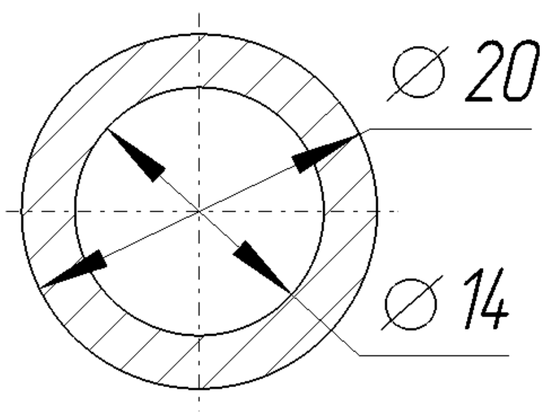

Fig 3.8. Axis cross section with attenuation

Geometrical characteristic

$$I_{kp.o} = \frac{\pi}{32} \times (D^4 - d^4) - 4 \times d_{hole} \times \delta \times R_{ave}^2 = \tag{3.64}$$

$$= \frac{3{,}14 \times (2{,}0^4 - 1{,}4^4)}{32} - 4 \times 0{,}5 \times 0{,}3 \times 0{,}85^2 = 0{,}76\ [cm^4]$$

Tangential stresses in cross section:

$$\tau_{axis}^P = \frac{M_{KP}^P \times D}{2 \times I_{kp,o}} = \frac{2090 \times 2{,}0}{2 \times 0{,}76} = 2750\ [\frac{kg}{cm^2}] \tag{3.65}$$

(See. Static Strength Reference 000.00.0000.013 МП-74, p.3).

Torsional stresses at banding:

$$\tau_{kp.o}^P = f\left(\frac{D}{\delta}\right) = 6000\ [\frac{kg}{cm^2}] \tag{3.66}$$

Where $\frac{D}{\delta} = \frac{2{,}0}{0{,}3} = 6{,}66$ (See. reference material for static strength calculating. 000.00.0000.003 МП-74).

$$\eta = \frac{\tau_{kp.o}^P}{\tau_{shaft.o}^P} = \frac{6000}{2750} > 2 \tag{3.67}$$

Calculation case 2.2. The direction of the force - perpendicular to the plane of the layout (rotation) of the handrail.

Bending moment in cross section E - E:

$$M_{E-E}^P = P_{hh}^P \times l_{E-E} = 100 \times 30{,}7 = 3070\ [kg \times cm] \tag{3.68}$$

Sectional stresses:

$$\sigma_{1,2}^{P} = \frac{M_{bend.\ E-E}^{P}}{W_x} = \frac{3070}{0,597} = \pm 5140\ [{}^{kg}/_{cm^2}] \tag{3.69}$$

$$\eta_{\text{Экв}} = \frac{\sigma_B}{\sigma_{1,2}^{P}} = \frac{8500}{5140} = 1,65 \tag{3.70}$$

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Conclusion

The handrail support arm lever of the airstrait is an important structural element of the construction. It takes torsion, compression and rupture loads, as a result of loading from the hand rest of the passengers. Since the lever is directly related to the safety of people on board, it must comply with all safety standards and criterions, meet the requirements of the calculated load. It was determined the loads acting on lever, eye and at the most loaded cross-sections of the structure. During the analysis it was determined that:

- Load acting on lever is equal to $125\ kg$;
- Eye strength calculation at shear, rupture and compession satisfy safety criterion for aviation design standart $\eta_{comp} = 8 > 1,5$;
- The most responsibility ross-sections sactisfy the safety criterion 1,5 for sectional stresse.
- Axial cross-secton was checked with taking into account an attenuation and also satisfy sectional stresse safety criterion $\eta_{екв} = 1,65 > 1,5$.

According to this analysis, conclusion gives us results that choosen material satisfy the requirements for lever arm consruction. The geometrical parametrs was choosen right. Lever arm satisfy whole spectr of demands and can be used in design of such construction types.

CONCLUSION

During the execution of dyploma project was done the preminary design of the middle range aircraft with capacity up to 100 passengers, its analytical and project calculation. According to this analyze was determined next results:

- preliminary design of the middle range aircraft with capacity up to 100 passengers with different variant of layouts on 20, 36, 44, 90 passengers, with taking into account geometrical and safety requirements for passanger equipment displacment;

- was done calculation of the main geometrical parameters of the landing gear and choosing current type of tires that can carry calculated loads and satisfy requirements on landing gear, that is equal 92 kN and 25 kN for the nose landing gear and main landing gear respectively:

- was choosen the main nessesary parametrs of aircraft construction

- was determined the center of gravity position of the airplane, that are in the range of 26,6-34,5%;

- Choosing and installation of turbofan engines type “Д-436” according to required calculated thrust of 65kN provides high cruise speed and good thrust-to weight ratio.

The maximum level of passenger comfort provides:

-rational layout and convenient service facilities;

- ergonomic optimization of common and individual space;

- modern interior design;

- low noise;

- special layouts, which give possibility to take a conference on board.

The strength calculation in special part demonstrate my ability to perform engeenering analysis and calculation, with taking into account safety factor and various conditions of loading.

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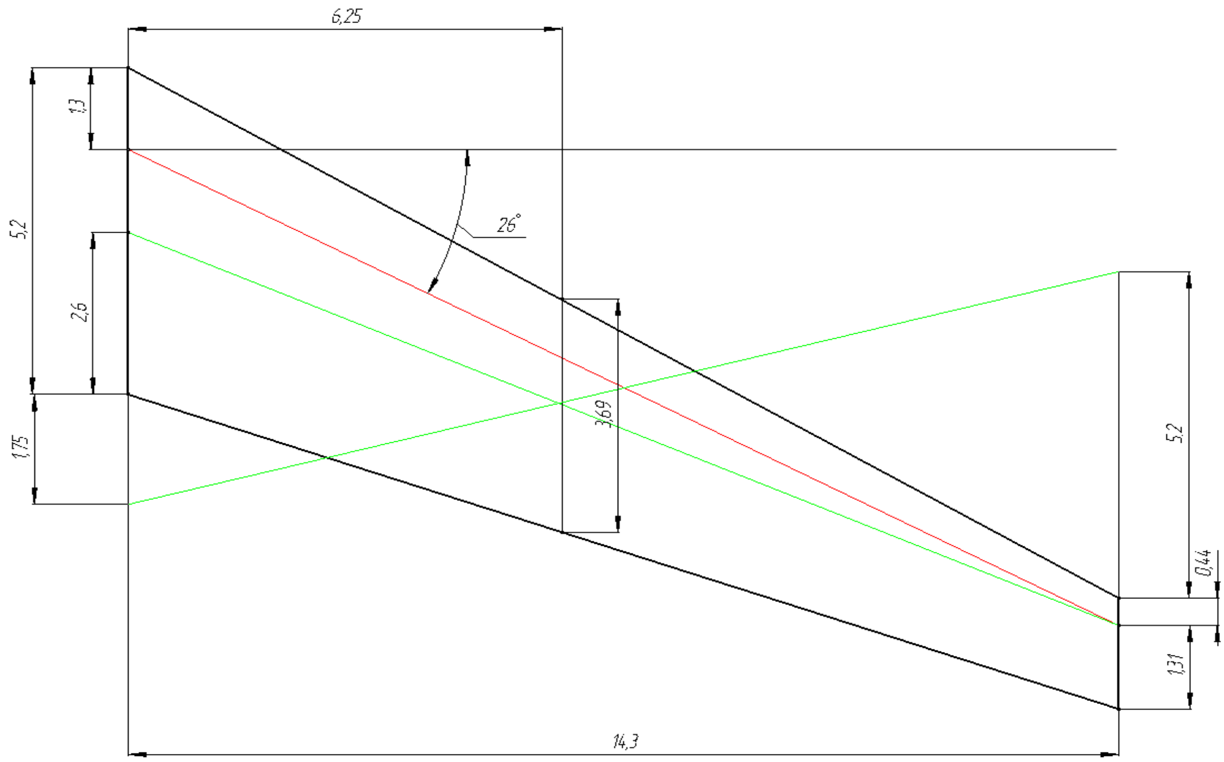
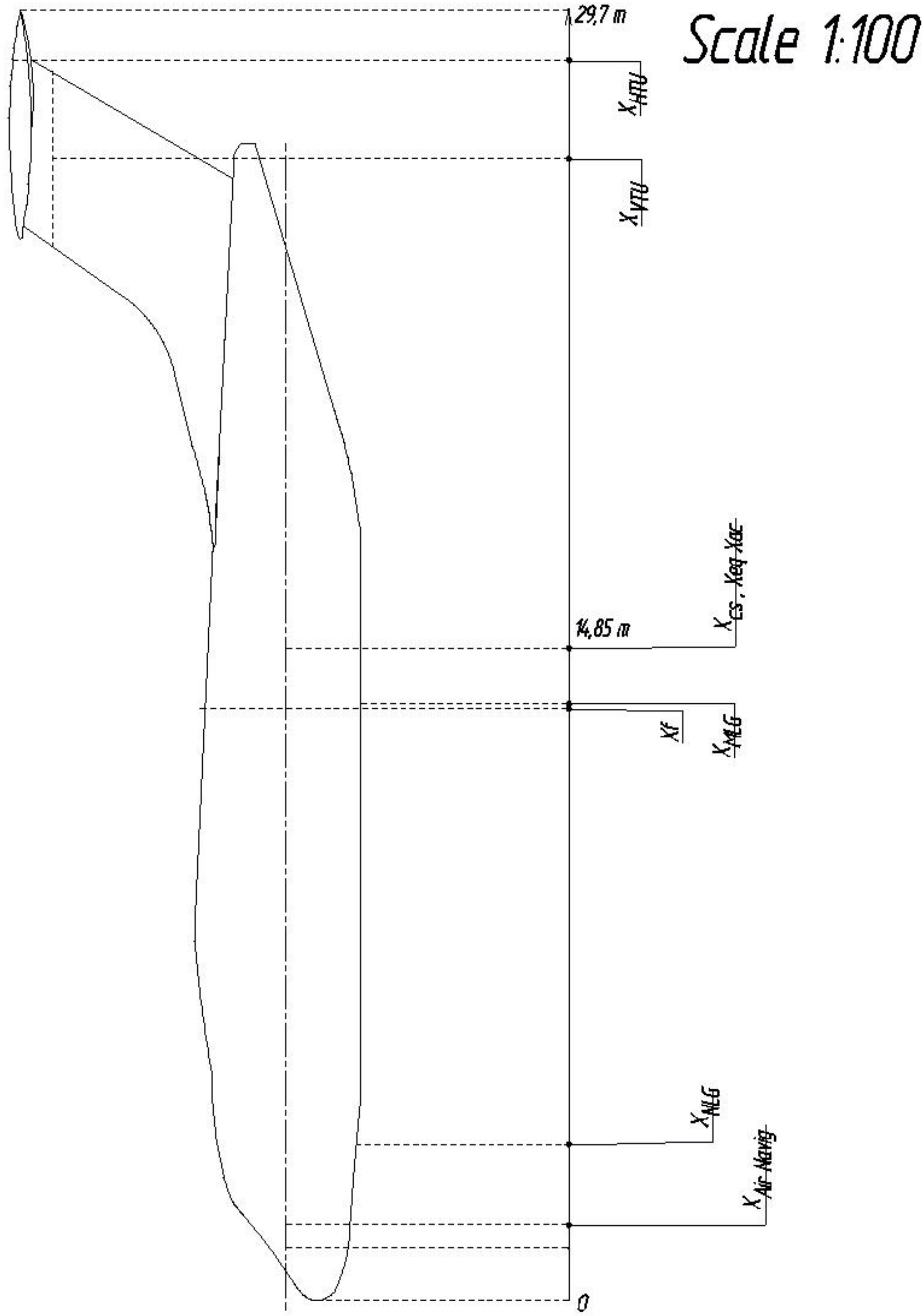
Appendix A



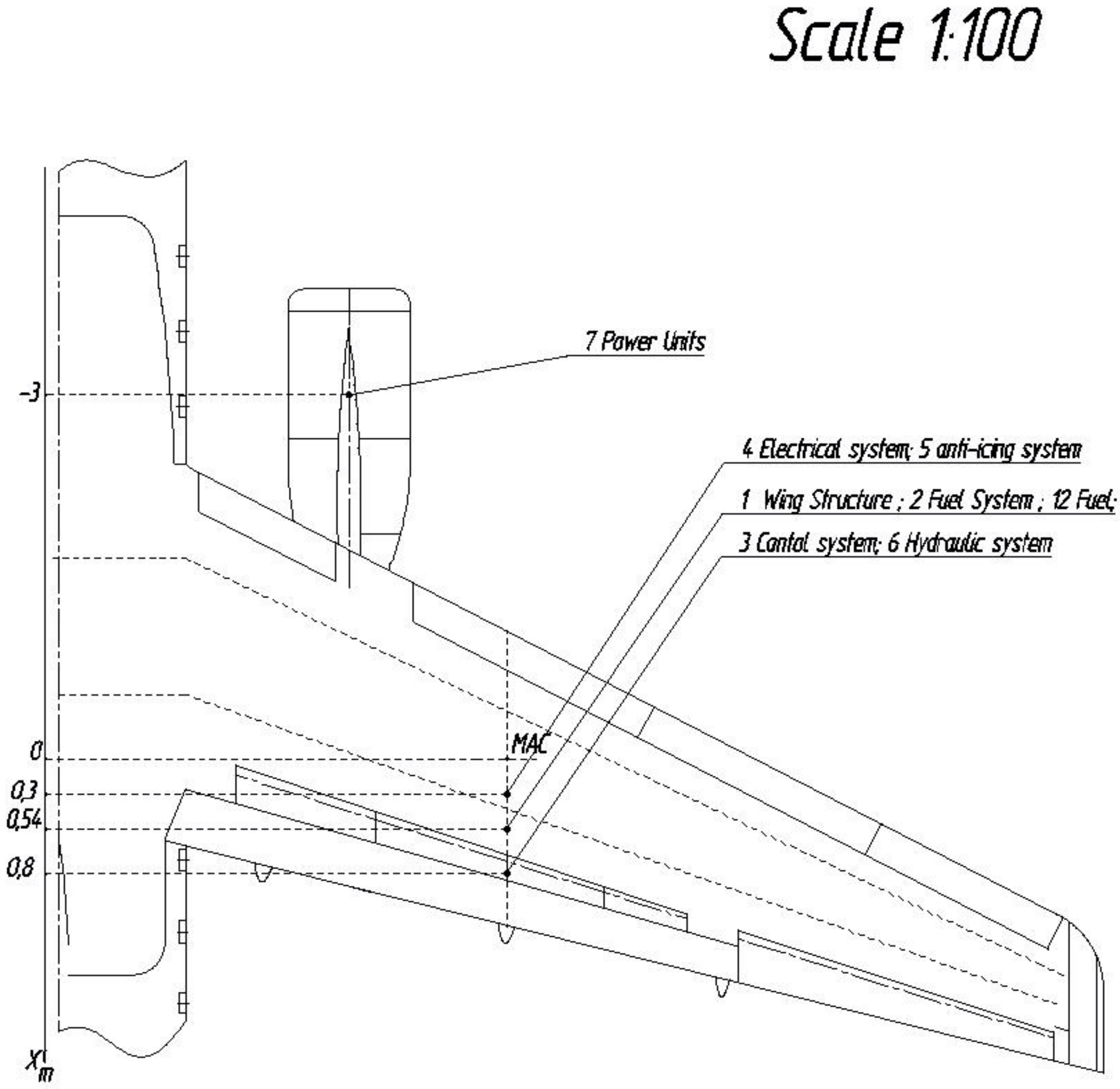
Aircraft Design Department				*NAU 20 06 I 00 00 00 78 EN*			
Performed by	*Ihnatov R.*			*Appendix*	*Letter*	*Sheet*	*Sheets*
Supervisor	*Zakiev V.*						
Adviser					*402AF 134*		
Stand.contr.	*Khizhnyak S.V.*						
Head of dep	*Ignatovych S.*						

Appendix B



Ch.	Sheet	Doc. №	Sign.	Date	NAU 19 12M 00 00 00 92 EN	Sh.

Appendix C



Scale 1:100
7 Power Units
4 Electrical system; 5 anti-icing system
1 Wing Structure ; 2 Fuel System ; 12 Fuel;
3 Contol system; 6 Hydraulic system
MAC
-3
0
0,3
0,54
0,8
X_m