

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
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ДОПУСТИТИ ДО ЗАХИСТУ

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« _____ » _____ 2022 р.

ДИПЛОМНИЙ ПРОЕКТ
(ПОЯСНЮВАЛЬНА ЗАПИСКА)
ВИПУСКНИКА ОСВІТНЬО-КВАЛІФІКАЦІЙНОГО РІВНЯ
«БАКАЛАВР»

Тема: «Аванпроект пасажирського дальньо-магістрального
літака місткістю 240 пасажирів»

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Київ 2022

**MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY**

Aircraft Design Department

PERMISSION TO DEFEND

Head of the department

Dr.Sc., Professor

_____ **Sergiy IGNATOVYCH**

« ___ » _____ 2022

BACHALOR DEGREE THESIS

ON SPECIALTY

"AVIATION AND AEROSPACE TECHNOLOGIES "

Theme: «Preliminary design of the long-range passenger aircraft with
240 passengers capacity»

Performed by: _____ **Liyu LIU**

Supervisor: Dr. of Science, Professor _____ **M. V. KARUSKEVICH**

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Kyiv 2022

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty

Aircraft Design Department

Educational degree «Bachelor»

Speciality 134 "Aviation and Space Rocket Technology"

APPROVED BY

Head of the Department

Dr.Sc., Professor

_____ Sergiy IGNATOVYCH

«___» _____ 2022

TASK

for bachelor diploma work

1.Theme:

«Preliminary design of the long-range passenger aircraft with 240 passenger capacity»

Confirmed by Rector's order from 10.05.2022 year № 489

2.Period of work execution 2022/05/23 to 2022/06/19

3.Work initial data:

Maximum payload – $n = 240$ passengers; Flight range with maximum payload – $L = 10800$ Km; Cruise speed – $V_{cr} = 870$ Km/h at operating altitude $H_{op} = 12.5$ Km; Landing speed – $V_{land} = 240.06$ km/h.

4.Explanation notes (list of topics to be developed):

selection of design parameters;choice and substantiations of the airplane scheme;calculation of aircraft masses;determination of basic geometrical parameters;aircraft layout;center of gravity position calculation;determination of basic flight performance;description of the aircraft design;engine selection;special part;

5.List of the graphical materials:

general view of the airplane (A1×1);layout of the airplane (A1×1);assembly drawing of the Roller Module for cargo hold and container compartment.(A3×2).

6. Calendar Plan

Task	Time limits	Done
Task receiving, processing of statistical data	23.05.2022–28.05.2022	
Aircraft geometry calculation	28.05.2022–31.05.2022	
Aircraft layout	31.05.2022–03.06.2022	
Aircraft centering	03.06.2022–05.06.2022	
Graphical design of the parts	05.06.2022–12.06.2022	
Completion of the explanation note	12.06.2022–14.06.2022	
Defense of diploma work	14.06.2022–19.06.2022	

7. Date: 23.05.2022

Supervisor

M.V. KARUSKEVICH

Student

Liyu LIU

ABSTRACT

Explanatory note to the diploma work «Preliminary design of the long-range passenger aircraft with 240 passengers capacity» contains:

50 pages, figures, tables, 16 references and 4 drawings

Object of the work is a process of the development of the long-range passenger aircraft with 240 passengers capacity.

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

The methods of design are: Comparative analyze of the planes-prototypes and selection of the most advanced technical decisions for wing, fuselage, tail unit, landing gear, high lift devices, primary flight control surfaces. For the acceptable range of center of gravity position the iterative method for the units mass location have been used.

The diploma work contains explanatory notes with calculations, drawings of the long-range passenger aircraft with 240 passengers capacity, preliminary design of the Roller Module for cargo hold and container compartment.

AIRCRAFT, PRELIMININARY DESIGN, LAYOUT, CENTER OF GRAVITY POSITIONS, ROLLER MODULE.

NAU 22 12L 00 00 00 65 KV

<i>Performed by</i>	<i>Liyu LIU</i>			ABSTRACT	<i>Letter</i>	<i>Sheet</i>	<i>Sheets</i>
<i>Supervisor</i>	<i>Karuskevich M.V.</i>						
<i>Adviser</i>							
<i>Stand.contr.</i>	<i>Khizhnyak S.</i>				402 AF 6.51101		
<i>Head of dep.</i>	<i>Ignatovych S.</i>						

LIST OF ABBREVIATIONS

RPK	Revenue passenger-kilometres
LG	Landing gear
APU	Auxiliary power unit
LP	Low pressure
HP	High pressure
IATA	International aviation transport association
ICAO	International civil aviation organization
FAR	Federal aviation regulation
CS	Certification specification
CCAR	Chinese civil aviation regulation
RM	Roller Module
CM	The center of the mass

LIST OF DRAWINGS

				<i>NAU 22 12L 00 00 00 65 KV</i>			
<i>Performed by</i>	<i>Liyu LIU</i>			ABSTRACT	<i>Letter</i>	<i>Sheet</i>	<i>Sheets</i>
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Introduction

Before the outbreak of the COVID-19, the passenger turnover of civil aviation in China increased steadily from 2015 to 2019. According to statistics, the average annual growth rate was as high as 13%, with a very large increase. Among them, the passenger turnover of international routes increased the fastest. The main reason is that with the development of China's economy and the trend of economic globalization, more and more people begin to go abroad by plane.

Moreover, under the general trend of economic globalization, international trade and international exchanges are increasing day by day. At the same time, the continuous development of air passenger transport also makes the economic cost of traveling by plane lower and lower. This also shows that the world's demand for long-range large passenger aircraft carrying out international routes is also gradually increasing.

Compared with cargo aircraft, passenger aircraft are in great demand for developing countries. In China, for example, as people's income levels continue to improve, more and more people will choose faster and more timely aircraft travel. Relatively speaking, aircraft cargo transportation has no great advantages over traditional ship, road or train transportation, and is only suitable for some special cargo requiring timeliness. So in my opinion, China's demand for international passenger flights will grow rapidly in the future. The design, R & D and manufacturing of long-range wide body passenger aircraft is the goal of China's future development. At present, only Boeing and Airbus have the capacity to produce wide body aircraft in the world. In order to break through the technological monopoly, COMAC is cooperating with Russia in the development of cr929 aircraft, which is a wide body aircraft with dual channel layout, with a maximum takeoff weight of 200 tons, carrying about 300 passengers and a range of 12000 kilometers.

Therefore, I intend to design a long-range dual channel wide body airliner with a passenger capacity of 240 and a range of more than 10000 kilometers to meet the passenger transport requirements of international long-range routes. At the same time,

considering that the passenger plane is to transport passengers and their luggage, not just cargo, the passenger plane should ensure the comfort of passengers and improve the safety of the aircraft.

Aircraft design is an applied science with strong practicality and broad theoretical basis. It comes from practice and is a scientific summary of the practical experience of aircraft model design for decades. After it gradually developed into an independent discipline, it was used to guide the practice of flight design. The subject of aircraft design is also the result of the comprehensive application of various advanced Aeronautical Science and technology. Its contents cover many disciplines and professional technical fields, such as aerodynamics, aircraft structure and strength, aero engines, aviation materials, avionics, automatic control and manufacturing technology. Without all kinds of Advanced Aeronautical Science and technology, and without a solid theoretical foundation, the discipline of aircraft design cannot progress and develop.

In order to form the concept of aircraft preliminary design, the best design parameters must be selected first. The selection of aircraft optimal design parameters is a multidimensional optimization task. Its shape means the whole complex flight technology, weight, geometry, aerodynamics and economic characteristics.

The aircraft is a cantilevered lower monoplane with a turbojet engine installed under the wing and a front three-point landing gear with a front single column landing gear and two main landing gears. A new supercritical airfoil with high aspect ratio swept back wing is adopted. The cross section of the fuselage is circular. The tail wing adopts the traditional structure. The rudder and elevator are equipped with pneumatic balancing devices.

According to the thickness and order of design contents, aircraft design can be roughly divided into three different stages with internal relations:

- one Conceptual design
- two Preliminary design
- three Detail design

The task of the preliminary design stage is to modify and supplement the aircraft design scheme previously drafted to further clarify and specify it, and finally draw a complete overall design scheme. The work in this stage includes: modifying, supplementing and perfecting the geometric shape design of the aircraft, and giving a complete three-dimensional drawing and theoretical shape of the aircraft; Comprehensively arrange various airborne equipment, systems and payloads; Preliminary arrangement of load-bearing system and main load-bearing components of aircraft structure; Carry out detailed weight calculation and center of gravity positioning; The aerodynamic performance, maneuverability and stability are calculated accurately; Draw the general layout of the aircraft in detail. The first step in developing the project is to select the aircraft to be analyzed as a prototype. The first overall idea is to select representative and successful aircraft, because the success of these aircraft reflects the wisdom and efforts of numerous aircraft engineers. A successful aircraft must have its unique advantages, which can better reflect the needs of the modern aviation market, and it is worth studying.

PART 1. PRELIMINARY DESIGN OF THE PLANE

1.1 Analysis of similar planes and brief description of the designed plane

Firstly, in order to have a concept of aircraft preliminary design, we need to select the optimal design parameters. As a multidimensional optimization task, it is very necessary to optimize the selection of aircraft design parameters, including geometric shape, aerodynamics, weight, flight control and economic characteristics.

The aircraft I need is a cantilevered lower monoplane, whose wing shape is based on a new supercritical shape, a swept wing with high aspect ratio. The turbojet engine is mounted under the wing. The landing gear adopts the front three-point landing gear, which is composed of a front wheel single column landing gear and two main landing gears under the fuselage. The rudder and elevator of the tail wing are equipped with pneumatic balancing device and adopt traditional structure.

Choosing an airliner with a payload that can accommodate 240 passengers and their luggage and a maximum range of more than 10000 kilometers as a prototype is my top priority. I collected three kinds of aircraft with different operation technical parameters, and their parameters and characteristics are very consistent with the aircraft we want to design. It is shown in Table 1.1 below.

The prototypes we selected for comparison are as follows:

The first step in this project is to select an aircraft as the prototype of our design. The primary goal is to choose those more successful aircraft, because those successful aircraft have gathered the wisdom and efforts of countless aircraft engineers, and have passed the test of time. A successful aircraft must also meet the needs of the current aviation market, have relatively good economy and reflect unique advantages, which is very worthy of our study.

Table 1.1 - Parameters of similar passenger aircraft

Name and dimensions	Boeing 787-8	Airbus 330-200	Airbus 330-300
The purpose of airplane	Passenger	Passenger	Passenger
Crew/flight attend, numbers	2/6	2/6	2/8
Passenger's seat	242	246	300
Maximum take-off weight, mtow, kg	227930	242000	242000
Max payload, kg	43,318	49,400	45,600

The form of the cross-section fuselage	circular	circular	circular
Flight Range with MTOW, km	13,620	13,450	11,750
Cruise speed, km/h	903	871	871
Cruise altitude, km	13	11.5	11.5
Number and type of engines	2*Genx-1b	2*Trent 700	2*GE CF6
Take off run at MTOW, m	2600	2,770	2,770
Thrust (each engine), KN	280	300	250

Table 1.1 - Parameters of similar passenger aircraft

The aircraft considered in this project is a long-range dual channel wide body airliner. Its fuselage design adopts a semi-integral fuselage with circular cross-section. The wing is a suspension type lower single wing mechanism. Two turbofan engines with large culvert ratio are installed under the wing respectively. It can carry 240 passengers, with a maximum effective load of 49400 kg, a cruising speed of 870 km / h, a flying altitude of 12.5 km and a maximum takeoff distance of 10800 km. The designed aircraft fuselage is a wide body fuselage with a length of 50.4m. Finally, I chose Airbus 330-200 as the prototype of my course project.

1.2. Geometry calculations for the main parts of the aircraft

The selection of aircraft design parameters is the most important work in the process of aircraft overall design. The so-called aircraft overall design, in short, is the process of knowing the design requirements, solving the design parameters and determining the aircraft overall scheme. The aircraft design parameters are the design variables to determine the aircraft scheme. To determine an overall scheme, it is necessary to determine a set of design parameters, including wing and tail area, aspect ratio, sweep angle, maximum diameter and length of fuselage and other geometric parameters; The mass of the aircraft and its components; And the thrust of the engine.

1.2.1. Wing geometry calculation

The plane shapes of modern aircraft wings include delta wings, swept wings and straight wings. From the aerodynamic point of view, the swept wing can effectively increase the critical Mach number, delay the generation of shock wave, and avoid premature wave resistance in the subsonic condition. Therefore, for the high subsonic

large civil aircraft I designed, like many other large civil aircraft, the swept wing is the best choice.

The fore-and-aft position of the wing is determined by the longitudinal static stability and maneuverability of the aircraft, which can not be determined until the aircraft centroid positioning stage. There are usually three kinds of up and down positions of wings on the fuselage: middle wing, upper wing and lower wing. These three types have their own advantages and disadvantages, and are used in modern aircraft. Similarly, similar to many large civil aircraft, the lower single wing is usually used because the engine is closer to the ground when installed under the wing, making it easier to disassemble and install the aircraft during maintenance.

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

According to my prototype aircraft $m_0=242900 \text{ kg}$.

According to my initial data $P_0=5832 \text{ Pa}$.

Full wing area with extensions is:

$$S_{wingfull} = \frac{m_0 \cdot g}{P_0} = \frac{242900 \cdot 9.8}{5832} = 408.16 \text{ (m}^2\text{)}.$$

Relative wing extensions area is 0.1.

Wing area is:

$$S_w = 408.16 \cdot 0.9 = 367.34 \text{ (m}^2\text{)}.$$

Wing span is:

$$l_w = \sqrt{S_w \cdot A_R} = \sqrt{367.34 \cdot 10.06} = 60.8 \text{ (m)}.$$

Root chord is:

$$b_r = \frac{2S_w \cdot \eta_w}{(1+\eta_w) \cdot l} = \frac{2 \cdot 367.34 \cdot 3}{(1+3) \cdot 60.8} = 9.06 \text{ (m)}.$$

Tip chord is:

$$b_t = \frac{b_r}{\eta_w} = \frac{9.06}{3} = 3.02 \text{ (m)}.$$

For a trapezoidal-shaped wing, the on-board chord is:

$$B_{ob} = b_0 \cdot \left(1 - \frac{(\eta_w - 1) \cdot D_f}{\eta_w \cdot l_w} \right) = 8.389 \text{ (m)}.$$

The force scheme of the wing is selected by determining the type of internal design of the wing. In order to meet the strength standard while maintaining a relatively light wing structure, I chose the design scheme of the box-spar type with two spars .

Wing spar position:

0.2 C_{root} to C_{tip}

0.6 C_{root} to C_{tip}

We employ a triple – slotted flap wing on contemporary aircraft; the wing also has three longerons.

I use the geometrical method of mean aerodynamic chord determination (figure 1.1). Mean aerodynamic chord is equal

$$b_{MAC} = 6.5433 \text{ (m)}.$$

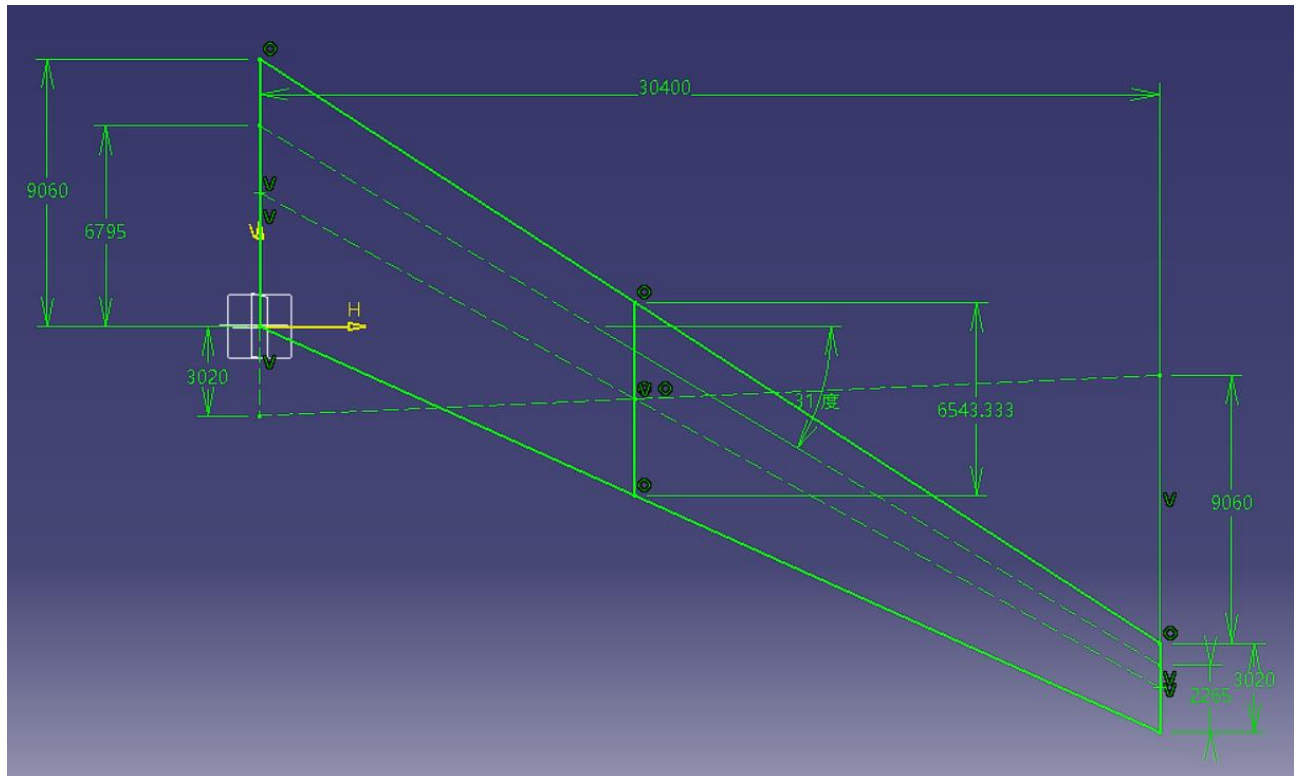


Figure 1.1 – Determination of mean aerodynamic chord

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:

$$l_{ail} = 0.3 \cdot \frac{l_w}{2} = 0.3 \cdot \frac{60.8}{2} = 9.12 \text{ (m)}.$$

Aileron area:

$$S_{ail} = 0.065 \cdot \frac{S_w}{2} = 0.065 \cdot \frac{367.34}{2} = 11.94 \text{ (m}^2\text{)}.$$

High Lift Devices. The purpose of calculating the geometric parameters of the wing high-lift devices is to offer the high coefficients of wing during landing and taking

off, which were predicted in early calculations based on the high-lift device selection rate and type of airfoil.

Where $C_{y_{maxl}}$ 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:

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

$b_s = 0.1..0.15$ – slats.

To pick the structural dynamic scheme, kinematics of the high lift device, and hinge mounting scheme, we must utilize data and experience from domestic and foreign aircraft manufacture. It is worth noting that the bulk of present high-lift device components are accomplished by longeron structurally-power systems.

1.2.2. 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} .

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.

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.

Fuselage length is equal:

$$l_f = \lambda_f \cdot D_f = 9 \cdot 5.6 = 50.4 \text{ (m)}.$$

Fuselage nose part aspect ratio is equal:

$$\lambda_{np} = \frac{l_{np}}{D_f} = \frac{7.56}{5.6} = 1.35.$$

Length of the fuselage rear part is equal:

$$50.8 \cdot 0.3 = 15.24 \text{ (m)}.$$

Take off angle 14...15°.

In the process of determining the fuselage length, we seek to approach the minimum middle section S_{ms} from one side and the layout requirements from the other side while determining the fuselage length. The size of the cabin or cargo cabin determines the middle part of the fuselage of the passenger cargo aircraft.

From a design point of view, a circular cross-section is convenient because it will be the strongest and lightest in this case. For the design consideration of forming a diameter exceeding 5000mm, we follow the circular cross section.

For a passenger cargo aircraft, the middle of the fuselage comes first from the size of the passenger compartment or cargo compartment. One of the main parameters to determine the middle of the passenger plane is the height of the passenger compartment.

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

I choose the next parameters:

Cabin height is equal:

$$H_{cabin} = 0.296 + 0.333 \cdot D_f = 0.296 + 0.333 \cdot 5.6 = 2.16 (m).$$

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

$$B_{cab} = n_{eco} \cdot b_{eco} + b_{aisle} + 2\delta = 2 \cdot 1600 + 1000 + 2 \cdot 600 = 5.4 (m).$$

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

$$B_{cab} = n_{bus} \cdot b_{bus} + b_{aisle} + 2\delta = 3 \cdot 1400 + 2 \cdot 600 = 5.4 (m).$$

The length of passanger cabin is equal:

$$\begin{aligned} L_{cab} &= 2 \cdot L_1 + (n_{rows} - 1) \cdot L_{seatpitch} + 2 \cdot L_2 \\ &= 3 \cdot 1200 + (27 - 1) \cdot 870 + (4 - 1) \cdot 960 + 2 \cdot 300 \\ &= 30.57(m). \end{aligned}$$

1.2.3. Layout and calculation of basic parameters of tail unit

Determining the position of tail unit is one of the most important tasks in designing aircraft aerodynamic layout. In order to ensure the longitudinal stability when the aircraft is overloaded, the center of gravity of the aircraft should be located in front of the aircraft aerodynamic center, and the distance between the two centers

(related to the average value of the wing aerodynamic chord) determines the rate of longitudinal stability.

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

Where m_x^{Cy} – is the moment coefficient; x_T, x_F – center of gravity and focus coordinates. If $m_x^{Cy}=0$, than the plane has the neutral longitudinal static stability, if $m_x^{Cy}>0$, 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 H_{tu} and V_{tu} 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:

$$S_{VTU} = \frac{l_w \cdot S_w}{L_{VTU}} \cdot A_{VTU} = \frac{60.8 \cdot 367.34}{19.63} \cdot 0.1 = 113.7(m^2).$$

Area o horizontal tail unit is equal:

$$S_{HTU} = \frac{b_{MAC} \cdot S_w}{L_{HTU}} \cdot A_{HTU} = \frac{6.5433 \cdot 367.34}{19.63} \cdot 0.65 = 122.4 (m^2).$$

Values L_{htu} and L_{vtu} depend on some factors. First, their value is influenced by the following factors: pitch back and wing position, aircraft stability and control conditions, and the length of the front and tail of the fuselage.

Determination of the elevator area and direction:

Altitude elevator area:

$$S_{el} = 0.2765 \cdot S_{HTU} = 33.85 \text{ (m}^2\text{)}.$$

Rudder area:

$$S_{rud} = 0.2337 \cdot S_{VTU} = 0.2337 \cdot 113.7 = 26.57 \text{ (m}^2\text{)}.$$

Choose the area of aerodynamic balance.

$$0.3 \leq M \leq 0.6,$$

$$S_{eb} = (0.22 \dots 0.25) S_{ea},$$

$$S_{rb} = (0.2 \dots 0.22) S_{rd}$$

Elevator balance area is equal:

$$S_{eb} = 0.235 \cdot S_{HTU} = 28.764 \text{ (m}^2\text{)}.$$

Rudder balance area is equal:

$$S_{rb} = 0.22 \cdot S_{VTU} = 25.014 \text{ (m}^2\text{)}.$$

The area of altitude elevator trim tab:

$$S_{te} = 0.10 \cdot S_{el} = 3.385 \text{ (m}^2\text{)}.$$

Area of rudder trim tab is equal:

$$S_{tr} = 0.05 \cdot S_{rud} = 1.3285 \text{ (m}^2\text{)}.$$

1.2.4. Luggage compartment

Due to the standards, I choose the unit load on floor $K = 600 \text{ kg/m}^2$

The cargo compartment area is defined as follows:

$$S_{cargo} = \frac{M_{bag}}{0.4K} + \frac{M_{cargo}}{0.6K} = 30 (m^2).$$

The volume of the cargo compartment is:

$$V_{cargo} = v \cdot n_{pass} = 0.2 \cdot 240 = 48 (m^3)$$

Luggage compartment design similar to the prototype , Since the seats in the cabin are designed as double channels, the luggage rack is arranged above the seats on both sides and above the middle seat, which can also leave a safe space above the channel, which is more conducive to the emergency evacuation of passengers and improve the safety.

1.2.5. Galleys

According to international standards, for aircraft with hybrid layout, the aircraft meal includes at least two dishes. For flights with a flight time of less than 3 hours, if food is not distributed to passengers, in this case, the crew must provide cabinets for water and tea. For flights with flight time less than one hour, buffet and toilet can not be provided. Kitchen cabinets must be fixed, preferably between the cockpit and passengers or cargo, and have separate doors. Refreshments and food should not be placed near toilet facilities or connected to wardrobe.

Volume of buffets(galleys) is equal:

$$V_{galley} = 0.1 \cdot 240 = 24 (m^3).$$

Hight of cabin:

$$H_{cabin} = 0.296 + 0.333 \cdot D_f = 0.296 + 0.333 \cdot 5.6 = 2.16 (m).$$

Area of buffets(galleys) is equal:

$$S_{galley} = \frac{V_{galley}}{H_{cab}} = \frac{24}{2.16} = 11.11 (m^2).$$

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

The food weight is:

$$W_{food}=(0.8+0.4)*240=288 (kg).$$

Galley design similar to prototype , It includes a sink, a water heater, a microwave oven, etc. it also adopts a fixed and detachable integrated tea cabinet and dining cabinet, as well as eight dining cars used by the crew to distribute food.

1.2.6. Lavatories

The number of bathroom facilities on an aircraft depends on the number of passengers and flight time. The plane I designed lasts more than 4 hours, so according to international standards, one toilet is allocated to every 40 passengers on average.

The number of lavatories I select is determined by the original airplane.

The number of lavatory is:

$$N_{lav}=240/40 = 6$$

Area of lavatory:

$$S_{lav}=1.5*6=9 (m^2).$$

Each toilet covers an area of 1.5 square meters and is designed with a toilet, a sink with a mirror and a trash can.

1.2.7. Landing gear design

For the aircraft with front three-point landing gear, the main fulcrum contacts the runway first, which will not cause adverse consequences. At this time, a head-on force is generated on the main fulcrum. Under the action of this force, the nose sinks and all fulcrums of the aircraft are stressed. During this movement, the angle of attack and the lift on the wing decrease. If the shock absorber on the strut can effectively absorb the energy of the aircraft, the aircraft will not leave the runway.

When the aircraft with the front three-point landing gear lands and taxis, due to the increase of landing speed, there may be driving errors, but there is no danger. The safety of landing is greatly improved, which is very in line with the design requirements of passenger aircraft.

Main wheel axel offset is:

$$e = 0.2673 \cdot b_{MAC} = 0.2673 \cdot 6.5433 = 1.749 \text{ (m)}.$$

With the large wheel axial offset the lift-off of the front gear during take off 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:

$$B = 0.4526 \cdot L_f = 0.4526 \cdot 50.4 = 22.811 \text{ (m)}.$$

The last equation means that the nose support carries 6...10% of aircraft weight. Front wheel axial offset will be equal:

$$d_{ng} = B - e = 21.062 \text{ (m)}.$$

Wheel track is:

$$T = 0.6072 \cdot B = 0.6072 \cdot 22.811 = 13.85 \text{ (m)}.$$

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 (arched, balloon, half balloon) and the pressure in it is determined by the runway surface, which should be used. We install breaks on the main wheel, and 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:

$$P_{NLG} = \frac{(9.81 \cdot e \cdot k_g \cdot m_0)}{(B \cdot z)} = \frac{(9.81 \cdot 1.749 \cdot 1.75 \cdot 198748)}{(22.811 \cdot 2)} = 160805.29 (N).$$

Main wheel load is equal:

$$P_{MLG} = \frac{(9.81 \cdot (B - e) \cdot m_0)}{(B \cdot n \cdot z)} = \frac{(9.81 \cdot (22.811 - 1.749) \cdot 198748)}{(22.811 \cdot 2 \cdot 4)} = 225028.26 (N).$$

According to the load on the wheels, I will choose the following tire type on the table 1.2.

Table 1.2 – Aviation tires for designing aircraft

Main gear		Nose gear	
Tire size	Ply rating	Tire size	Ply rating
H31x13.0-12	20	24x8.0-13	18

1.2.8. Choice and description of power plant

The engine has a great influence on the flight performance of aircraft in the fields of speed performance, high altitude performance, endurance and acceleration. During

the overall design of the aircraft, the first question that arises is which engine will most effectively meet the design requirements of the aircraft, which requires all aircraft designers to have a deeper understanding of the performance and performance of the aircraft engine.

From the perspective of aircraft design, the basic requirements for aircraft engines mainly include the following:

1. the thrust (or power) has good speed and height characteristics

The engine of the aircraft is the core of the power plant, and its function is to provide necessary thrust or power for the aircraft. Therefore, it is first necessary to select an engine that can provide sufficient thrust or power within the whole flight speed and altitude range of the aircraft. Therefore, not only static thrust or sufficient engine power is required, but also good high-speed and high-altitude performance is required, which is the basic requirement to be met

2. low fuel consumption

The fuel consumption rate of the engine has a direct impact on the use economy of the aircraft. Moreover, when the designed aircraft has the same fuel capacity, it will also affect the range and endurance time of the aircraft. Therefore, it is required that the fuel consumption rate of the engine should be as low as possible.

3. the engine shall be light in weight

Engine weight is the main component of aircraft fixed weight, which generally accounts for a large proportion. Therefore, choosing a lighter engine will often greatly reduce the structural weight of the aircraft, which can also improve and improve various flight performance of the aircraft.

4. the engine size should be small

Considering the requirements of aircraft structure, the engine design should be compact and its overall dimensions should be as small as possible, especially the windward area of the engine, so as to better reduce the engine volume and reduce the external aerodynamic resistance caused by the engine loading on the aircraft.

5. high reliability and low failure rate

Obviously, once the engine fails, the safety of the aircraft will be seriously threatened. Therefore, the engine must be stable and reliable in all flights. This means that all components of the engine and its system must be mature and reliable, and hold the product qualification certificate approved and issued by the competent authority, which confirms the possibility of using the engine on the aircraft.

6. long service life

In other words, the longer the total engine life and maintenance life, the better. This is particularly important for civil aircraft.

7. convenient maintenance

This requirement is also important. If it is convenient to maintain, control and inspect the engine, it not only ensures the safety, but also shortens the aircraft waiting time between the two flights and improves the aircraft attendance rate. This is beneficial to improve the efficiency of aircraft.

The above lists seven basic requirements for aircraft engines.

The unit fuel consumption of turbofan engine with large bypass ratio is close to that of turboprop engine, so it has been widely used in many civil and military high subsonic aircraft. In particular, considering the importance of civil aviation to the economy and the desire to minimize oil consumption, recently some countries in the Americas and Europe are developing and developing dual circuit engines, sometimes called "Super Fans", which further reduce the unit fuel consumption by more than 20%. Therefore, the advantages of such engines, coupled with the high applicability of turbofan engines and low fuel consumption turboprop engines, It is a promising engine and can be widely used in civil aircraft.

Aircraft engines have many different installation positions, but for large passenger aircraft, the engine is usually installed under the wing.

GECF6, PW4000-100, Trent700 are high-bypass turbofan engines, in various modifications installed on passenger aircraft A330-200. Here we choose the newly developed trent700 with the largest thrust to weight ratio and the highest economic benefit as our preferred engine.

Compared with the double rotor turbofan engine adopted in the United States, Trent's three rotors can work at the optimal speed respectively, reducing the number of rotor stages, blades and adjustable blades. Due to the small number of rotor stages, the rotor can be shorter, improve the rigidity of the rotor and reduce the performance degradation rate. The high-pressure turbine of double rotor engine is generally two stages. The second stage works at high speed and needs to cool the rotor blades, while the medium pressure turbine of three rotors works at low speed and does not need cooling, which reduces the requirements of cooling air and ensures that the oil consumption rate of the engine is reduced by 1.5%. The assembly of this kind of coupling is more complex than that of Trent rotor, which is not equipped with a three tooth ball coupling.

Table 1.3 – Examples of engines for similar planes

Model	Thrust	Bypass ratio	Dry weight
GE CF6	293-310kN	5.1	5092kg
PW4000-100	287-311kN	4.9	5851kg
Trent700	300-320kN	5.0	4785kg

1.3 Aircraft center of gravity calculation for the Loading and Configurations cases

The aircraft with conventional control system must meet the minimum requirements for vertical static stability specified in the design specification or airworthiness rules. In consideration of various errors that may occur during aircraft development, the corresponding margin shall be added as an index for preliminary determination of aircraft center of gravity.

In addition, during the design, it should be noted that during the flight of the aircraft, not only the loading and fuel consumption will cause the change of the center of mass position, but also the retraction and retraction of the landing gear will cause the movement of the center of mass of the aircraft.

1.3.1. Trim-sheet of the equipped wing

Mass of the equipped wing contains the mass of its structure, mass of the equipment placed in the wing and mass of the fuel. Regardless of the place of mounting (to the wing or to the fuselage), the main landing gear and the front gear are included in the mass register of the equipped wing. The mass register includes names of the objects, 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 1.4.

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

$$X'_w = \frac{\sum m'_i x'_i}{\sum m'_i}$$

$$Y'_w = \frac{\sum m'_i Y'_i}{\sum m'_i}$$

Table 1.4 - Trim sheet of equipped wing

N	Object name	Mass		Center of gravity, X _M	MTM
		units	total mass m(i)		Mass moment
1	Wing (structure)	0.12619	25080.01	2.6172	65639.4
2	Fuel system	0.0126	2504.22	2.6172	6554.06
3	Airplane control, 30%	0.0012	238.49	3.9258	936.29
4	Electrical equipment, 10%	0.00269	534.63	0.6543	349.81
5	Anti-ice system , 40%	0.00696	1383.28	0.6543	905.08
6	Hydraulic systems , 70%	0.00854	1697.30	3.9258	6663.29

7	Power plant	0.09014	17915.1	-2.5	-44788
8	Equipped wing without landing gear and fuel	0.24832	49353.10	0.734	36260.1
9	Nose landing gear	0.0050295	999.60	-19.21235	-19205
10	Main landing gear	0.0285005	5664.41	3.59865	20384.3
11	Fuel	0.39618	78739.98	2.6172	206078
	Total	0.67803	134757.10	1.80	243518

1.3.2 Trim-sheet of the equipped fuselage

Origin of the coordinates is chosen in the projection of the nose of the fuselage on the horizontal axis. 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 1.5.

The CG coordinates of the FEF are determined by formulas:

$$X_f = \frac{\sum m_i' X_i'}{\sum m_i'}$$

$$Y_w' = \frac{\sum m_i' Y_i'}{\sum m_i'}$$

Table 1.5 - Trim sheet of equipped fuselage masses

N	Objects names	Mass		C.G coordinates Xi, M	mass moment
		units	total mass		
1	Fuselage	0.07769	4940.38	24.192	119518
2	Horizontal tail	0.00932	592.66	47	27855.4
3	Vrtical tail	0.00962	1911.95	48	91773.9
4	Radar	0.0024	476.99	0.5	238.498
5	Radio equipment	0.0018	357.74	0.8	286.197
6	Instrument panel	0.0042	834.74	1.5	1252.11
7	Aero navigation equipment	0.0036	715.49	2	1430.99

8	Flight control system 70%	0.0028	556.49	18	10016.9
9	Fydraulic sys 30%	0.00366	727.41	21	15275.8
10	Electrical equipment 90%	0.02421	4811.6	18	86610.4
11	Not typical equipment	0.0021	417.37	5	2086.85
12	Lining and inslulation	0.0057	1132.8	24.192	27406.2
13	Anti ice 20%	0.00348	691.64	0.6543	452.52
14	Airconditioning system 40%	0.00696	1383.28	18	24899.1
15	Passenger seats (bussiness)	0.000966047	192	10	1920
16	Passenger seats (economic class)	0.00652082	1296	27	34992
17	Seats of flight attendence	0.000130819	26	26	
18	Seats of pilot	0.000161008	32	4	128
19	Emergency equipment	0.001921305	381.85		
20	Lavatory1, galley 1	0.00505	1003.67	28	28103
21	Lavatory2, galley 2	0.00505	1003.67	28	28103
22	Operational items	0.001812	360.1		
23	Additional equipment	0.0048	953.9		
24	Equipped fuselage (without payload)	0.183952	24800.0	20.255927	502349
25	Passengers(bussiness)	0.009298207	1848	10	18480
26	Passengers(economy)	0.083683861	16632	27	449064
27	On board meal	0.001811339	360	28	10080
28	Baggage	0.024151186	4800	23	110400
29	Cargo, mail	0.011295711	2245	25	56125
30	Flight attend	0.001811339	360	26	9360
31	Crew	0.000774851	154	4	616
32	TOTAL	0.316778494	51199.08	22.58	1156474
	TOTAL fraction	0.994808494			

Table 1.5 - Trim sheet of equipped fuselage masses

1.3.3. Range of the aircraft centering

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

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

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

$$X_{MAC} = \frac{m_f x_f + m_w \cdot x'_w - m_0 C}{m_0 - m_w},$$

where:

m_0 – aircraft takeoff mass, kg;

m_f – mass of fully equipped fuselage, kg;

X_f -coordination of fully equipped fuselage;

m_w – mass of fully equipped wing, kg;

X_w -coordination of fully equipped wing;

C – distance from MAC leading edge to the C.G. point, determined by the designer.

$C = (0,22...0,25) B_{MAC}$ – low wing ;

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

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

For swept wings;

at $X = 30^\circ...40^\circ$ $C = (0,28...0,32) B_{MAC}$

Knowing the wings position relatively to fuselage on the layout drawing, we connect the wings power elements and the fuselage. After the wings and fuselage arrangement a C.G. calculation takes place. C.G. positioning is called the relative position of centre of masses relatively to MAC leading edge, presented percents:

$$\bar{X}_T = \bar{X}_C = \frac{X_{C.G.} - X_{MAC}}{b_{MAA}} \cdot 100\% = \frac{C}{b_{MAA}} \cdot 100\%$$

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

Table 1.6 - Calculation of the C.G. positioning variants

Name	mass in Kg	Coordinate	mass moment
Object	mi	Xi,, M	Kg.m
Equipped wing (without fuel and landing gear)	49353.10336	21.74304169	1073086.6
Nose landing gear (extended)	999.603066	5	4998.0153
Main landing gear (extended)	5664.417374	27.811	157533.11
Reserve fuel	2504.2248	23.62553456	59163.65
fuel for flight	78739.98264	23.62553456	1860274.2
Equipped fuselage (without payload)	24800.08153	20.821431	516373.19
Passengers(bussiness)	1848	10	18480
Passengers(economy)	16632	27	449064
Baggage	4800	23	110400
cargo, mail	2245	25	56125
Crew	154	4	616
Nose landing gear (retracted)	999.603066	4	3998.4123
Main landing gear (retracted)	5664.417374	29	164268.1

Table 1.6 - Calculation of the C.G. positioning variants

Table 1.7 - Airplanes C.G. position variants

No.	Object name	Mass mi Kg	Mass moment Kg*m	center of mass Xcg	C.G.point XC
1	Take off mass (L.G. extended)	187740.412	4246950.079	22.621	0.19
2	Take off mass (L.G. retracted)	187740.412	4252685.468	22.651	0.20
3	Landing weight (LG extended)	109000.430	2445839.547	22.438	0.16
4	Ferry version	159711.188	3618616.468	22.657	0.20
5	Parking version	80817.205	1811154.547	22.410	0.16

1.4 brief description of aircraft components

The center of gravity point will be in this range: 16.52% - 20.29%. The most forward centre of gravity is located on the 16.52% from the leading edge of the mean aerodynamic chord in parking version, and the most aft center of gravity on the 20.29% when the aircraft in ferry version.

The aircraft is based on Airbus A330-200, on which the latest technologies in relevant neighborhoods are adopted for various improvements. As a result, a new long-range dual channel wide body aircraft is designed. Its passenger capacity can reach 240, the maximum range with full load can exceed 10000 km, and the cruise speed is 870 km / h at sub high speed. The aircraft has excellent flight performance indicators and good economy.

1.4.1 aircraft fuselage

The aircraft is based on the Airbus A330-200 fuselage. The fuselage exterior and cabin width are the same as those of the prototype: 5.6m and 5.4m respectively, and there are many common components. Business class 2-2-2 6 seats and economy class 3-2-3 8 seats are typical seating arrangements. When necessary, the auxiliary power unit (APU) will provide air circulation and power for the aircraft cabin.

The cockpit layout of the aircraft is the same as that of its prototype A330-200. The general layout is adopted, and the electronic instrument display is used instead of the mechanical instrument. Different from the traditional control yoke, it uses side bar control. The electronic instruments include six main displays, electronic flight instrument system (EFIS) and electronic aircraft central display (ECAM). The aircraft cockpit is also equipped with navigation and flight displays. In addition, the aircraft also uses the A330 series general flight control system. Three primary flight control systems, one flight limit protection system and two secondary flight control systems are installed on the aircraft. The limit protection system is designed to prevent maneuvering beyond the aerodynamic and structural limits of the aircraft.

1.4.2 aircraft wings

The aircraft wing adopts the lower single wing layout, and the wing is similar to the A330-200. The wing span is 60.8m. On the aircraft, the engine is installed on the inner hanger under the wing; The wings are equipped with winglets.

Due to the use of small wings, the aircraft performance can be improved by 5% - 7%. Its main principle is to reduce the strong eddy current behind the wing tip when the aircraft passes through the air. This usually happens when the low-pressure air flow on the wing meets the high-pressure air flow under the wing at the wingtip. The negative effect of this is that the drag generated by eddy current decelerates the aircraft, and the thrust needs to be increased to offset the drag, thereby increasing fuel combustion. This is what designers don't want. Therefore, through the ingenious aviation design, the winglet can change and significantly reduce the eddy current, so that the aircraft consumes less fuel to maintain the same speed. In order to achieve large wingspan and high aspect ratio without significant weight loss, a 31 degree swept wing is used, as well as other design features that allow a maximum operating Mach number of 0.87. The thickness to chord ratio of the wing is 10.8% or 11.6%. The thickness to chord ratio of jet airliners ranges from 9.4% to 13%.

In order to integrate the aircraft into the aerodynamic characteristics developed for the former, the wing design is common to the A330-200 wing. The wing was designed with a span of 60.3m, which was later extended to 60.8m. The wing span was very similar to the prototype, and the wing area was only increased by less than 10m².

Structurally, the wing consists of three parts: the wing root part connected with the central wing box, the middle part and the wing tip part. The wings are also equipped with attached mechanical devices (flaps, ailerons, spoilers), which can significantly improve the takeoff and landing performance and maneuverability of the aircraft.

The structural part of the wing is mainly composed of wing beam, front wall, rear wall, wing rib, stringer and skin. The wing beam and front and rear walls bear the main load acting on the wing, while the skin, stringer and wing rib are mainly responsible for transmitting the load. Because the distance between the wing and the ground is relatively small, the lift coefficient increases due to the influence of the ground, so as to improve the takeoff and landing characteristics.

1.4.3 aircraft tail

The tail of the aircraft is swept back and consists of a vertical tail and a horizontal tail.

The vertical tail includes vertical stabilizer and rudder, and the horizontal tail includes horizontal stabilizer and elevator. Both the horizontal and vertical tail wings of the aircraft are made of composite materials, which account for only 10% of the structural weight.

The vertical and horizontal tail sections are symmetrical. The metric profile can maintain the same aerodynamic load characteristics with less resistance during rudder deflection in different directions. The thickness of the horizontal tail airfoil increases with the increase of the horizontal airfoil profile, so as to reduce the weight of the wing under the load of the vertical and horizontal tail airfoil profile.

1.4.4 aircraft cockpit

The pilot workplace is designed to provide either of them with safe control over the aircraft. The stability and controllability of the aircraft, the structure, characteristics and automation of flight navigation equipment and airborne systems, and the structure and configuration of display equipment are the characteristics of providing pilots with the ability to perform their duties without exceeding the existing load specifications.

The conical windshield with radio alarm is used in the cockpit to provide good protection for the pilot and meet the flight operation requirements under the expected conditions. The pilot can perform manual and automatic control anywhere.

According to the requirements of flight airworthiness standards, place devices and optical signal devices on the pilot control panel. Place control panel vertices in the most accessible area, and place quick use command radio control panels and automatic control systems.

The cockpit system top control panel contains fuel, hydraulic, power, antifreeze, air conditioning, engine and APU start, fire switch and alarm system panel.

The central control panel contains not only the traditional engine control lever, but also the navigation and landing equipment windows.

1.4.5 aircraft cabin facilities

In order to provide necessary convenience for long-time passengers. Cabin facilities include adjustable pilot seat, crew seat and passenger seat; Transparent windows, shading curtains, toilets, kitchens, etc.

There is a toilet and a small kitchen between the aircraft cockpit and the passenger compartment, three toilets are distributed between the aircraft passenger compartments, and there are two toilets and a large kitchen behind the passenger compartment. The area of all toilets is one square meter, and the total area of the two kitchens is 11 square meters. Each toilet is equipped with a wash basin and a vacuum toilet with a water tank.

The aircraft is also equipped with appropriate emergency equipment, including ropes, oxygen masks, smoke masks, oxygen devices, manual fire extinguishers, first aid kits, axes, emergency radio and radio beacons, evacuation route lights, emergency lighting and "exit" signs near each emergency exit, as well as crew, passenger and pilot life jackets, crew and passenger lifeboats. There are three first aid kits on the aircraft (one in the cockpit, one contained in the structure of the collision equipment, and one at the rear of the aircraft).

1.4.6 aircraft landing gear

The aircraft has;

Two main landing gears (MLG) with four-wheel bogie assembly and associated doors.

A nose gear (NLG) with two wheel assemblies and associated doors.

The main landing gear is located under both wings and retracts towards the fuselage centerline. The nose gear retracts forward into the fuselage compartment under the cockpit. The landing gear and landing gear door retraction are hydraulically and mechanically operated. Control, sequence and indication are electrical. In abnormal operation, the landing gear can be extended by gravity.

Each MLG has an outrigger component and a four-wheel bogie beam. The outriggers include a shortening mechanism, a bogie pitch adjuster and a hydro pneumatic shock absorber. In flight, when the MLG is extended, the bogie is placed behind the low position (rear) by the articulated link and the pitch adjuster. When the

MLG is fully extended, the folding base is mechanically locked by the locking lever (operated by the bottom locking actuator).

Each MLG pod has the following doors:

- Hydraulically operated main door
- Mechanical hinged door
- Rectifier door on MLG leg

When the main landing gear is retracted, all doors are closed. When the main landing gear is extended, the main door is closed and the hinged door remains open. When the aircraft is on the ground, a manual operating mechanism allows (maintenance personnel) to open the main door to enter the MLG cabin.

NLG pods have the following doors:

- Two hydraulically operated front doors
- Two mechanically operated rear doors
- Fixed fairing door on NLG leg

The NLG consists of a two axle assembly and an hydro pneumatic shock absorber. The NLG is supported longitudinally by a two-piece drawbar. When the NLG is fully extended, the drawbar is mechanically locked by the chain.

When NLG retracts, all doors are closed. When the NLG is extended, the front door is closed and the rear door remains open. The door opening mechanism allows the front door to open on the ground for access to the NLG cabin.

1.5 conclusions to part 1.

During this designing work I've got the next results:

- preliminary design of the long range aircraft with 240 passengers;
- the cabin layout of the long range aircraft with 240 passengers;
- the center of gravity of the airplane calculations;
- the calculation of the main geometrical parameters of the landing gear;
- the selection of wheels that meet a requirement for theoretical load with the landing speed in 240.6 km/h

- the applying of high-bypass turbofan engines type Trent700, which are located under the wing, provides high cruise speed and good thrust-to-weight ratio.

Finally, the geometric characteristics of the aircraft I designed are roughly the same as those of the selected prototype. As a newly designed aircraft, it not only absorbs the excellent design of the prototype, but also adopts many of the latest technologies, making the aircraft structure more reasonable. On the original basis, the safety, economy and maintainability are improved.

PART 2. ROLLER MODULE DESIGN

Roller systems (roller conveyor) are cylindrical devices on the aircraft floor that allows palletized cargo to move throughout the aircraft cargo/ramp compartment.

2.1. Contemporary designs.

Prior to the development of Roller Module for the plane considered in the part 1, the analysis of existing concepts and engineering decisions have been carried out. The fig.2.1 shows how much the contemporary plane are saturated with different floor devices to facilitate the loading/unloading processes.

Thus, inside the cargo compartment of the A320 one can find: Transport rollers, Continuous side guides, fixed YZ-guides with integrated rollers, longitudinal PDU, ball mats, lateral PDU, center roller track, XZ-latches, door sill latches, etc.

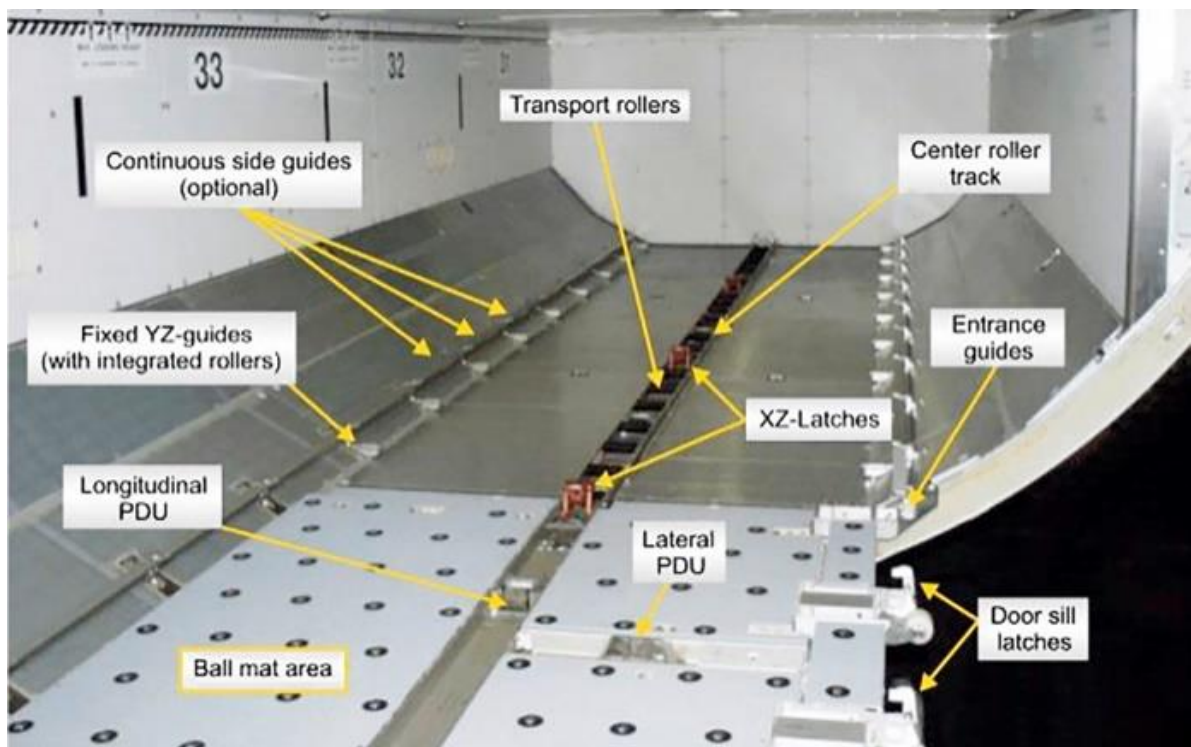
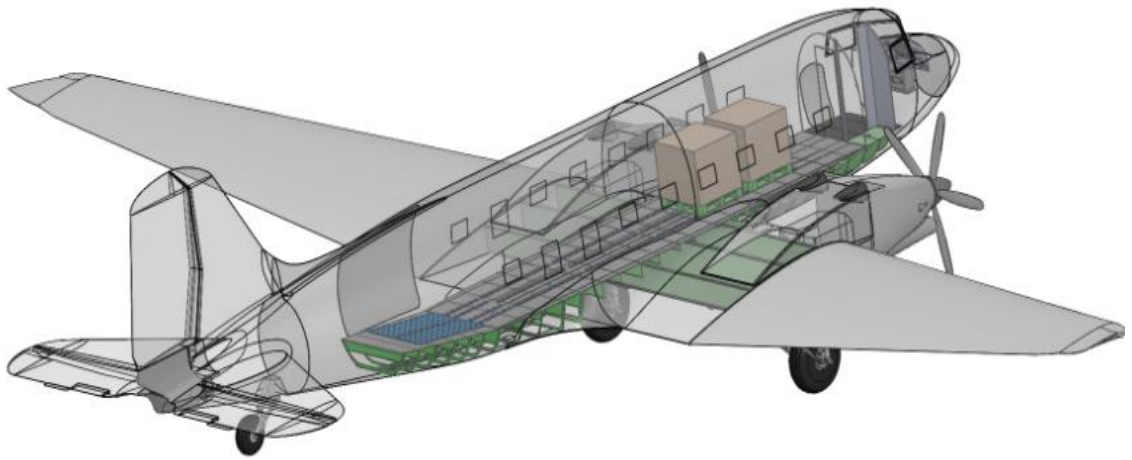
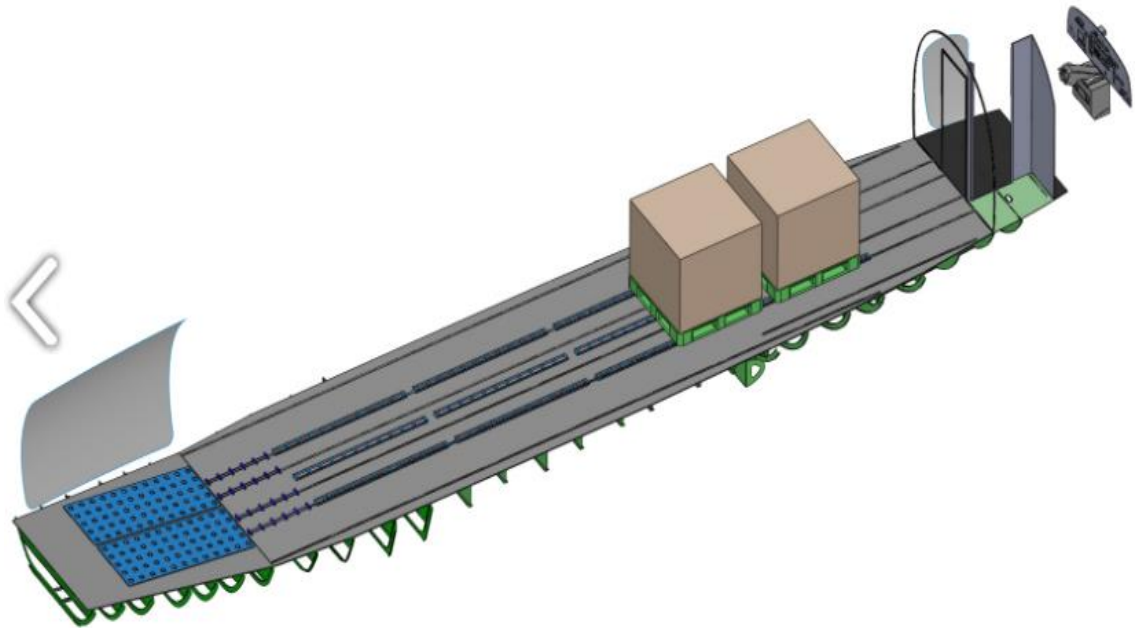


Fig.2.1 – Components of the contemporary aircraft (A320) cargo compartment

As an example the Douglas DC-3 BT-67 roller floor installation can be considered (fig.2.2).



a)



b)



c)

Fig.2.2 – Douglas DC-3 BT-67 roller floor: a – Aircraft; b – Sketch of the flooring system; c – fragment of the Roller Module System

This change is due to the installation of a cargo floor roller system. The roller deck system consists of two ankra ball pads located in the rear cargo door area and an ankra pallet unit located on the front floor of the cargo door. The transition between roller tray assembly and ball pad is a series of ankra modified roller blocks Change the roller to 1 degree to ensure a smooth transition from the washer to the roller tray.

As it is seen from the fig.2.3 the A330 airplane, selected as the prototype for the diploma work also is equipped by the roller system.



Fig.2.3 – A330 Lower Deck Cargo Loading System

Figure 2.4 shows another advanced design proposed by. Advanced aircraft roll systems, Inc. developed aero glide™, As a kind of copolymer aircraft cargo hold roller, it can improve the design flexibility and is a feasible, long-term and economic alternative to the traditional metal roller. Aero Glide™ The aircraft cargo ship can be seamlessly integrated into the aircraft cargo loading system under wear and tear without affecting or interrupting the existing system. Aero Glide™ The aircraft cargo hold roller has the same strength characteristics as the metal cargo hold roller. In addition, the roller has lower cost; High performance - low wear and low friction coefficient; Light weight chemical / corrosion resistance; Very durable - high impact resistance; No bearings - no maintenance, etc.



Fig.2.4 - Copolymer aircraft cargo roller developed by Aero-Glide™, According to the task on diploma work the conventional roller unit has been developed.

2.2. Preliminary dimensions of one Roller Module

In simplest form the Roller Module looks like a tray with rollers (fig.2.5). The proposed concept of the Roller Module for the passenger aircraft reflects the idea of this design, but adapted for particular loads on the floor, requirements for the attachment, etc.

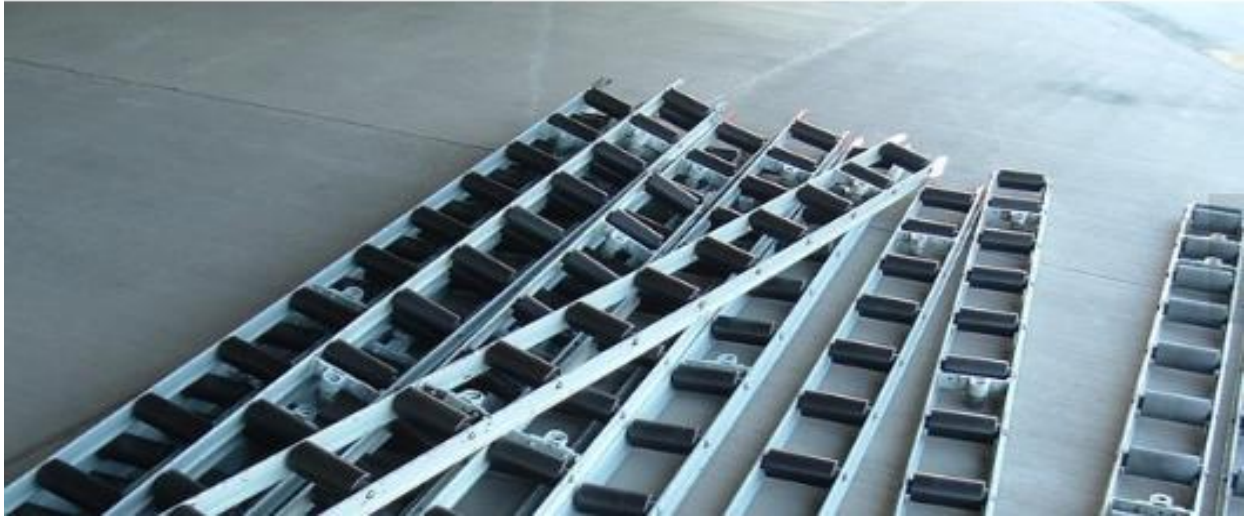
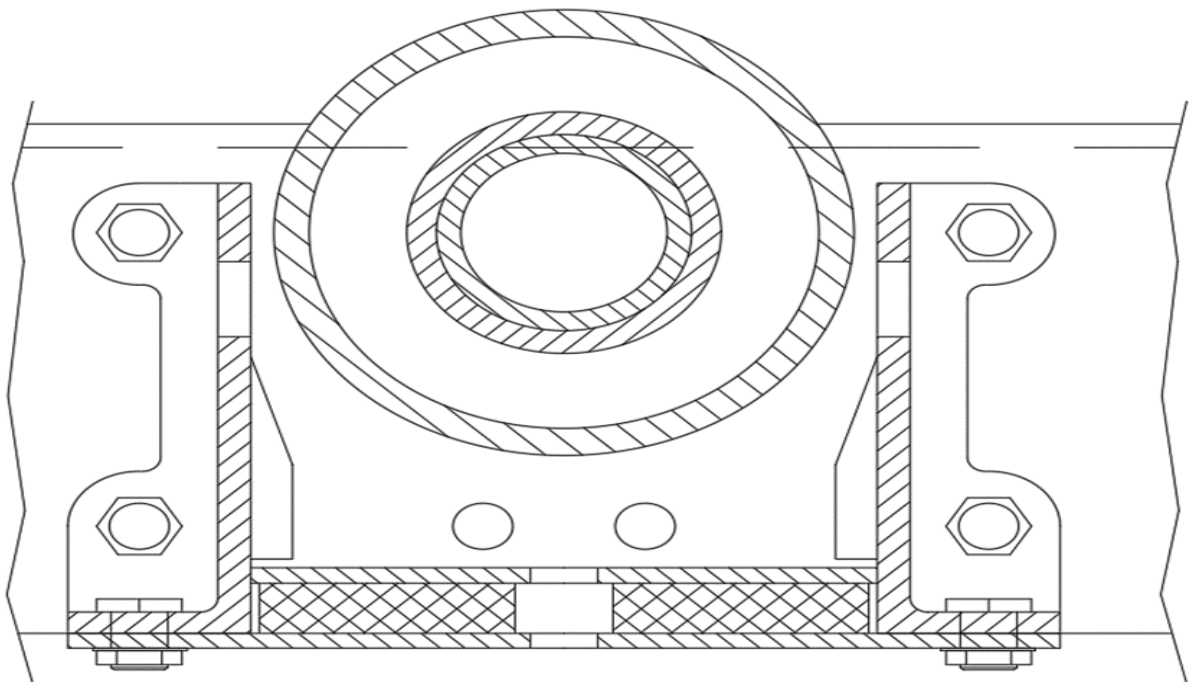


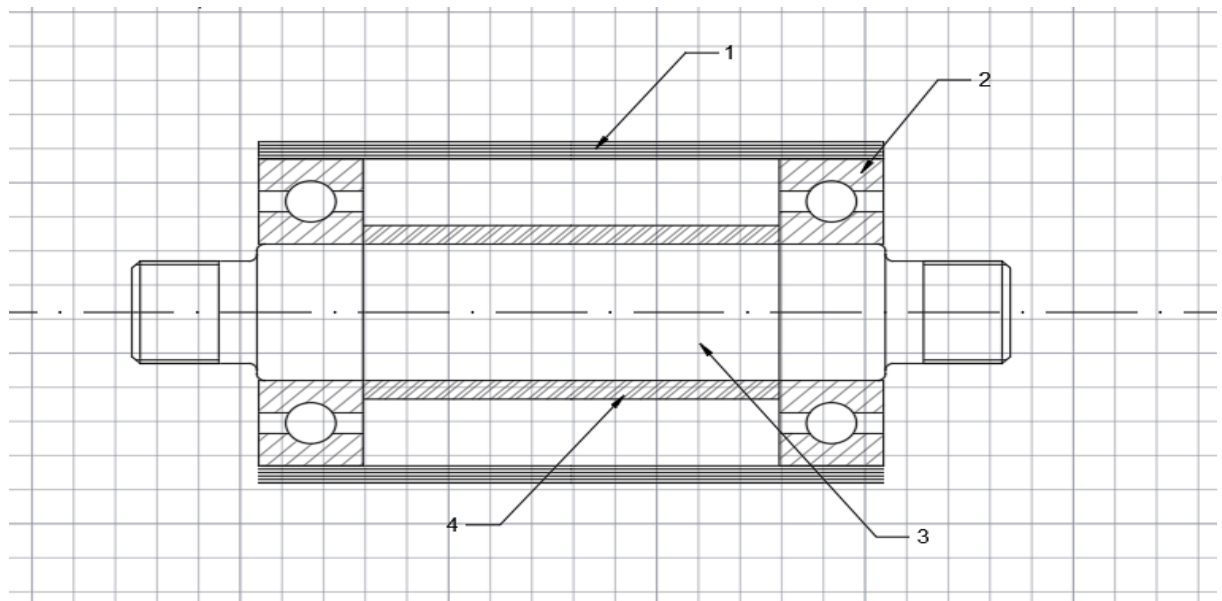
Fig.2.5 – Simplest roller module

The Roller Unit for designed plane has been developed on the base of known decisions developed by the ANTONOV. The material and dimensions were adapted for the loads calculated in the preliminary design stage as well as taking into account constructional materials available in China.

Below the assembly drawing of the Roller Unit is shown (fig.2.6).



a)



b)

Fig.2.6 – Roller unit for the designed plane: a – assembly drawing; b – Roller itself with bearings

2.3. Load on one Roller Module.

Load on the Roller unit has been calculated on the base of information about the acceptable maximum area load for similar planes and required number of Roller Unit on square meter of the cargo cabin floor.

From the data related to the Airbus plane the maximum area load is close to 700 kg/m².

According to the design there are 8 roller tracks installed on the board in A330-200F, and the distance between rollers in lateral direction is 600 mm, and the distance between rollers in longitudinal direction is 500 mm. so we can determine how many rollers on one m².

$$n = \frac{8 \times 2}{5.28} \approx 3 \left(\frac{\text{rollers}}{\text{m}^2} \right).$$

The maximum area load is 700kg/m².

The load for one roller (F_a):

$$F_a = \frac{\text{max area load} \times g}{n} = \frac{700 \times 9.8}{3} = 2287(N)$$

To provide stable movement of the containers inside the cargo compartment the number of Roller Unit on one square meter was found to be equal 10. Thus, the load on one Roller Unit is 70 kg.

This information is required for the selection of bearings, selection of the material, and assessment of the Roller Unit geometry.

2.4. Material for Roller Module Components.

Taking into account the experience of Roller Units design the material for the roller itself and the axis of unit have been selected.

The aluminum alloy 2024-T3 is proposed to use for the Roller itself. The characteristics of the alloy are presented in table 2.7.

Table 2.1 – Mechanical characteristics of the 2024-T3 aluminum alloy.

Material	Temperatures (°C)	Modulus of elasticity E_1 (MPa)		Yield strength (R_e) (MPa) 85 ± 5% humidity	Tensile strength (R_m) (MPa) 85 ± 5% humidity
		85 ± 5% humidity	Poisson's ratio ν_{12}		
2024-T3	-20	75,800	0.34	375	478
	25	73,200	0.34	350	450
	60	72,000	0.33	335	424

High strength steel 2.8 manufactured in China has been selected for the axis of the Roller Unit. The Characteristics of the steel 30CrMnSIA are shown in the table 2.2.

Table 2.2 – Characteristics of the steel 30CrMnSIA

Chemical Requirements, Composition, %

Grade	C	Si	Mn	P	S	Ni	Cr	Cu
30CrMnSiA	0.28- 0.34	0.90- 1.20	0.80- 1.10	0.025 max	0.025 max	≤ 0.40	0.80- 1.10	≤ 0.25

Mechanical properties

Yield strength σ_s /MPa (\geq)	Tensile strength σ_b /MPa (\geq)	Elongation δ_5 /% (\geq)	Reduction of area ψ /% (\geq)	Impact absorbing energy A_{ku2} /J (\geq)	Hardness HBS 100/3000 max
835	1080	10	45	39	229

2.5. Bearings

Selection of the bearing depends primarily on the dimensions of the components where they are installed and operational loads.

If the load will be mostly radial (perpendicular to the shaft), a radial bearing is used, and if the load will be mostly axial (same direction as the shaft), a thrust bearing is required. Axial loads are sometimes called thrust loads.

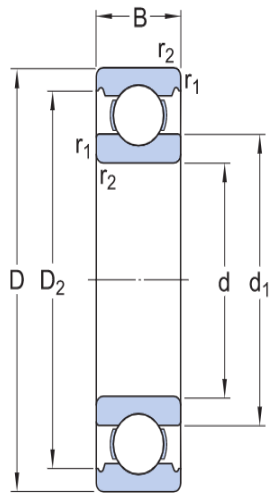
The bearing shown in fig.2.7 has been selected for the roller unit.



Fig.2.7– Ball bearing 16002 selected for the Roller Unit

Characteristics of the selected bearing are presented in the table 2.3.

Table 2.3 – Dimensions of the bearing 16002



DIMENSIONS

d	15 mm	Bore diameter
D	32 mm	Outside diameter
B	8 mm	Width
d_1	≈ 20.5 mm	Shoulder diameter
D_2	≈ 28.2 mm	Recess diameter
$r_{1,2}$	min. 0.3 mm	Chamfer dimension

2.6. Method for the lubrication

The major types of bearing lubrication are: grease lubrication, which uses semi-solid (i.e., like cream) grease; and oil lubrication, which uses lubricating oil.

Because grease is semi-solid, it tends not to leak out and can be easily affixed to the inside of the bearing. Since this makes it convenient as a sealing device, grease lubrication is widely applied for bearings.

On the other hand, oil lubrication is more effective as a lubricant than grease lubrication, and so is used in situations where such factors as high-speed rotation, a large cooling effect, or dirt filtering are required.

Comparison of the grease and oil lubrication is presented in table 2.4.

Table 2.4 – Grease and oil lubrication comparison

No.	Item	Grease lubrication	Oil lubrication
1	Sealing device	Simple	Slightly troublesome Care needs to be taken for the maintenance of the device
2	Lubricating ability	Good	Excellent
3	Rotation speed	Low/medium speed	Can be used in high-speed rotation
4	Replacement of lubricant	Slightly troublesome	Easy
5	Life of lubricant	Relatively short	Long
6	Cooling effect	No cooling effect	Good (but circulation is needed)
7	Filtration of dirt (removal of contaminants)	Difficult	Effective

After the analysis of all pros and cons of lubrication methods the grease lubrication has been selected.

2.7. Design details

For the tray the standard aluminum channel profile can be selected (fig.2.8).



Fig.2.8 - standard aluminum channel profile for the tray

The concept of the tray fasten to the fuselage beam is shown in fig.2.9.

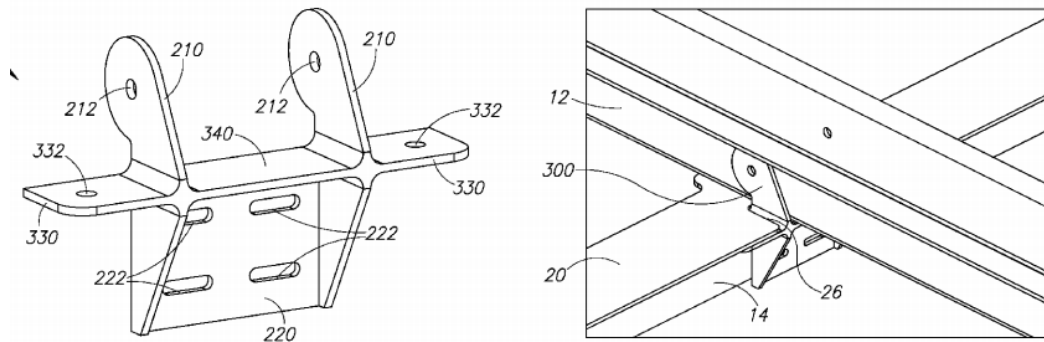


Fig. 2.9 - Attachment of the tray to the fuselage beam

2.8 conclusion to part 2

The roller system is designed for the facilitation of the loading and unloading processes.

Proposed design of the roller module is based on some early used systems adapted for the long-range aircraft presented in the part 1 of the diploma work. Along the roller design process the following steps have been carried out: geometry was defined according to the available space in the aircraft cargo compartment; load was taken to be equal the maximum area load for similar plane; material for structure and bearings were selected to withstand accepted loads, etc.

GENERAL CONCLUSION

In the preliminary design, the aircraft shall meet the use purpose, and its geometric characteristics shall provide necessary aerodynamic performance. During the design process, I determined the main geometric parameters of the wing, fuselage, tail, control surface and landing gear. In addition, the layout of cargo hold is determined. All these works meet the requirements of long-distance passenger aircraft.

In this part of the design work, I got the following results:

- Preliminary design of a long-range aircraft carrying 240 passengers;
- Cabin layout of long-range aircraft with 240 passengers;
- Calculation of main geometric parameters of landing gear;
- The selection of wheels shall meet the theoretical load requirements, and the driving speed shall be 240.6 km/h
- The trent700 high bypass turbofan engine located under the wing can provide high cruise speed and good thrust to weight ratio.

For the center of gravity of the aircraft, the forward center of gravity is the leading edge of the main aerodynamic chord, and the rearmost center of gravity is the leading edge of the main aerodynamic chord. The final center of gravity position of the equipped aircraft is the leading edge of the main aerodynamic chord. This meets the requirements of long-range passenger aircraft. The main components of the aircraft are briefly described. The designed aircraft is based on the selected prototype, and some geometric parameters are refined to meet the requirements of modern passenger aircraft.

The geometric characteristics of the aircraft I designed are roughly the same as those of the selected prototype. As a newly designed aircraft, it not only absorbs the excellent design of the prototype, but also adopts many latest technologies to make the aircraft structure more reasonable. On the original basis, the security, economy

and maintainability are improved. In the future, this airliner will be competitive in the market.

The roller deck system is designed to facilitate loading and unloading of cargo for aircraft cargo hold.

The proposed design of the roller module is based on some early use systems for long-range aircraft introduced in Chapter 2 of the graduation project. In the roller design process, the following steps are carried out: define the geometry according to the available space in the aircraft cargo hold; The load is the maximum area load of similar plane; The selected structure and bearing materials can bear acceptable loads, etc; Draw the roller unit diagram; Draw detailed assembly drawings.

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APPENDIX

INITIAL DATA AND SELECTED PARAMETERS

Passenger Number	240
Flight Crew Number	2
Flight Attendant or Load Master Number	8
Mass of Operational Items	3601.05 kg
Payload Mass	26400.00kg
Cruising Speed	870 km/h
Cruising Mach Number	0.8162
Design Altitude	12.5 km
Flight Range with Maximum Payload	10800 km
Runway Length for the Base Aerodrome	3.30 km
Engine Number	2
Thrust-to-weight Ratio in N/kg	2.6000
Pressure Ratio	34.8
Accepted Bypass Ratio	5.00
Optimal Bypass Ratio	5.00
Fuel-to-weight Ratio	0.4510
Aspect Ratio	10.06
Taper Ratio	3.00
Mean Thickness Ratio	0.11
Wing Sweepback at Quarter of Chord	31.0°
High-lift Device Coefficient	0.930
Relative Area of Wing Extensions	0.000

Wing Airfoil Type	supercritical
Winglets	no
Spoilers	yes
Fuselage Diameter	5.60m
Fineness Ratio of the fuselage	9.00
Horizontal Tail Sweep Angle	35.0°
Vertical Tail Sweep Angle	45.0°

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point	$C_y = 0.54913$
Induce Drag Coefficient	$C_x = 0.00894$

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

Cruising Mach Number	0.81619
Wave Drag Mach Number	0.82447
Calculated Parameter D_m	0.00828

Wing Loading in kPa (for Gross Wing Area):

At Takeoff	5.832
At Middle of Cruising Flight	4.597
At the Beginning of Cruising Flight	5.596

Drag Coefficient of the Fuselage and Nacelles 0.00948

Drag Coefficient of the Wing and Tail Unit 0.00895

Drag Coefficient of the Airplane:

At the Beginning of Cruising Flight	0.02999
At Middle of Cruising Flight	0.02805

Mean Lift Coefficient for the Ceiling Flight	0.54913
Mean Lift-to-drag Ratio	19.57675
Landing Lift Coefficient	1.466
Landing Lift Coefficient (at Stall Speed)	2.199
Takeoff Lift Coefficient (at Stall Speed)	1.841
Lift-off Lift Coefficient	1.344
Thrust-to-weight Ratio at the Beginning of Cruising Flight	0.449
Start Thrust-to-weight Ratio for Cruising Flight	2.268
Start Thrust-to-weight Ratio for Safe Takeoff	2.870
Design Thrust-to-weight Ratio R_o	3.013
Ratio $D_r = R_{cruise} / R_{takeoff}$ D_r	0.790

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

Takeoff	35.9228
Cruising Flight	57.6607
Mean cruising for Given Range	64.2440

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.02953
Block Fuel	0.36664

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.12619
Horizontal Tail	0.00932
Vertical Tail	0.00962
Landing Gear	0.03353
Power Plant	0.09014

No typical Equipment Weight Fraction 0.0021

(Build-in Test Equipment for Fault Diagnosis,
Additional Equipment of Passenger Cabin)

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed 299.80km/h

Acceleration during Takeoff Run 2.29m/s²

Airplane Takeoff Run Distance 1445m

Airborne Takeoff Distance 578m

Takeoff Distance 2024m

CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed 284.81 km/h

Mean Acceleration for Continued Takeoff on Wet Runway 0.36m/s²

Takeoff Run Distance for Continued Takeoff on Wet Runway 2229.30m

Continued Takeoff Distance 2807.68m

Runway Length Required for Rejected Takeoff 2908.73m

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight 135644kg

Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight
23.6min

Descent Distance 57.06km

Approach Speed 255.06km

Mean Vertical Speed 2.05m/s

Airborne Landing Distance 519m

Landing Speed 240.06km/h

Landing run distance	795m
Landing Distance	1314m
Runway Length Required for Regular Aerodrome	2195m
Runway Length Required for Alternate Aerodrome	1866m