МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Кафедра конструкції літальних апаратів

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
д-р техн. наук, проф.
_____________ С. Р. Ігнатович
«_____» ___________ 2021 р.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)
ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ
"БАКАЛАВР"

Тема: «Аванпроект дальньомагістрального пассажирського літака пасажиромісткістю 240 людини»

Виконав: ___________ **Лінь Тяньхун**

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Київ 2021

MINISRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
Department of Aircraft Design

APPROVED
Head of Department
Professor, Dr. of Sc.
_________S.R. Ignatovych
«___» _______ 2021

Diploma work

(EXPLANATORY NOTE)
OF EDUCATIONAL DEGREE
«BACHELOR»

Theme: «Preliminary design of long range cargo aircraft with 240 passengers»

Performed by: __________ **Lin Tianhong**

Supervisor: PhD, associate professor __________ **S.S. Yutskevych**

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

Kyiv 2021

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty

Department of Aircraft Design

Educational degree «Bachelor»

Major 134 "Aviation and space rocket technology"

APPROVED
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«___» _______ 2021

TASK
for bachelor diploma work
LinTianhong

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

2. Period of work execution: from 24.05.2021-16.06.2021

3. Work initial data:

- cruise speed 871 km/h,
- flight range13450km,
- operating altitude12.5 km,
- payload up to 49400kg.

Explanatory parameters (list of topics to be developed).

- Selection of design parameters.
- Selection and justification of aircraft solutions.
- Calculation of aircraft masses.
- Determination of basic geometrical parameters.
- Layout drawings of the aircraft.
- Calculation of the position of the centre of gravity.
- Determination of basic flight performance.

– Description of the aircraft design.;

– engine selection;

– special part

4. List of the graphical materials:

– general view of the airplane (A1×1);

– layout of the airplane (A1×1);

– assembly drawing of the winch (A1×1)

– Graphical materials are performed in AutoCAD, Solid Works, CATIA.

5. Calendar Plan

№ п/п	Task	Execution period	Signature
1	Task receiving, processing of statistical data	15.05.2021	
2	Aircraft take-off mass determination	19.05.2021	
3	Aircraft layout	19.05.2021	
4	Aircraft centering determination	25.05.2021	
5	Graphical design of the parts	25.05.2021	
6	Special part performing	06.06.2021	
7	Graphical design of the parts	09.06.2021	

6. Task date:«___» _______ 2021

Supervisor of diploma work:__________ S.S. Yutskevich

Task for execution is given for __________ Lin Tianhong

ABSTRACT

Explanatory note to the diploma work «Preliminary design of the long-range passenger aircraft with 240 passenger capacity» contains:
_56_sheets, _10_figures, _9_tables, _20_references and _3_drawings

Object of the design is development of cargo long-range aircraft with passenger capacity 240.

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

The methods of design are analysis of the prototypes and selections of the most advanced technical decisions, analysis of center of gravity position

The diploma work contains drawings of the long-range aircraft with a carrying capacity of 240 passengers, calculations and drawings of the aircraft layout, calculations and drawing.

PASSENGER AIRCRAFT, PRELIMININARY DESIGN, CABIN LAYOUT, CENTER OF GRAVITY DETERMINATION, LANDING GEAR SHOCK ABSORBER, SHOCK ABSORBER EXAMINATION CALCULATION,LANDING GEAR COOLING SYSTEM.

Format	№	Designation	Name	Quantity	Notes
			General documents		
A4	1	NAU 21 14L TT	Task of work	1	
	2		Long-range passenger aircraft	2	
A1		NAU 21 14L 00 00 00 22 GV	General view		
A1		NAU 21 14L00 00 00 22 FL	Fuselage layout		
A4	3	NAU 21 14L 00 00 00 22 EN	Long-range Passenger aircraft	56	
			Explanatory note		
A1	4	NAU 21 14L 32 00 00 22LG	Documentation for assembly units	1	
			Landing Gear		

Ch.	Sheet	Doc.№	Sign.	Date	NAU 21 13L 00 00 00 22 EN
Performed by	Lin Tianhong				List of diploma work
Supervisor	Yutskevych S.S.				
Adviser					
Stand. contr.	Khyzhnyak S.				
Head. of dep.	Ignatovych S.				

List	Sheet	Sheets

AF 402 134

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Introduction

In the past time, we can clearly see an increase in passenger traffic, especially in local airlines, which has significantly increased the demand for passenger transportation. In this regard, aircraft are needed for short-haul transportation, where economic losses can be avoided at low load factors. In order to ensure the profitability of aviation technology, in a highly competitive global market, a new civil aircraft is needed to meet the requirements of international air transport organizations, in particular:

-Flight safety;

- Increasing comfort operation;

- Reducing emissions of harmful gases, and others.

The plane of projection must also meet the following requirements:

-Comfortable passenger cabins that meet the highest requirements;

-take off and land on unpaved runways;

-Operate in a wide temperature range;

-Simple and reliable operation.

The long distance route for transporting 240 passengers and luggage is the main content of this diploma work

1.Project part

1.1 Analysis of prototypes and short description of designing aircraft

1.1.1Choice of the projected data

The selection of the optimum design parameters for an aircraft is a multidimensional optimisation task aimed at designing a suitable and excellent aircraft. Many complex technical, weight, geometric, aerodynamic and economic flight characteristics are contained in its structure. In the first stage of the design of the 'planar geometry appearance', methods such as transforming the co-ordinate system and approximating aerodynamics are widely used. The second stage uses complete aerodynamic calculations; and uses the aircraft's specified gross weight calculation formula as well as experimental data.

The prototype of the aircraft, taken for the design of the aircraft, is in the 240-passenger class. Aircraft like the A330-200, A330-200F and A330-300 will compete with the projected aircraft in this market segment. The statistics for the prototypes are presented in Table 1.1.

Table 1.1 – Operational-technical data of prototypes

PARAMETER	PLANES		
	A330-200	A330-200F	A330-300
The purpose of airplane	Passenger	Cargo	Passenger
Crew/flight attend. persons	2/8	N/A	2/8
Maximum take-off weight, m_{tow}, kg	242000	233000	242000
Most pay-load, $m_{K.max}$, kg	49400	68600	45600
Passenger's seat	243	12(Except for goods)	295
1	2	3	4

1	2	3	4
The height of the flight $V_{w.\ ек.}$, m	12527		
Range $m_{к.max}$, km	13430	7400(65 tons load) 5900(70 tons load)	11760
Take off distance $L_{зл.д.}$, m	2770	2580	2770
Number and type of engines	2×GE CF6 (except -200F) / PW4000 / Trent 700		
The form of the cross-section fuselage	circular	circular	circular
Extension of the fuselage	9,4	11	8,38
Extending the nose and tail unit part	5,64	5.65	4,2
Sweep back on 1/4 chord, ^{0}	30°		

The A330-200 was a shorter fuselage and longer-range version of the A330-300, used primarily as a replacement for the A300-600R from the same manufacturer and to compete with Boeing's 767-300ER.

Due to the shorter fuselage, the A330-200 used a higher vertical tail than the A330-300. In addition, with a maximum takeoff weight of 242 tons due to the addition of a central fuel tank, an A330-200 with a three-class cabin has a range of 13,450 km (7,250 nautical miles) with 253 passengers.

In terms of engines, the A330-200 uses the same engines as the A330-300, namely the General Electric CF6-80E1, Pratt & Whitney PW4000 or Rolls-Royce Trent 700, all of which meet the 180-minute ETOPS standard.So the same engine will be fitted to the aircraft.

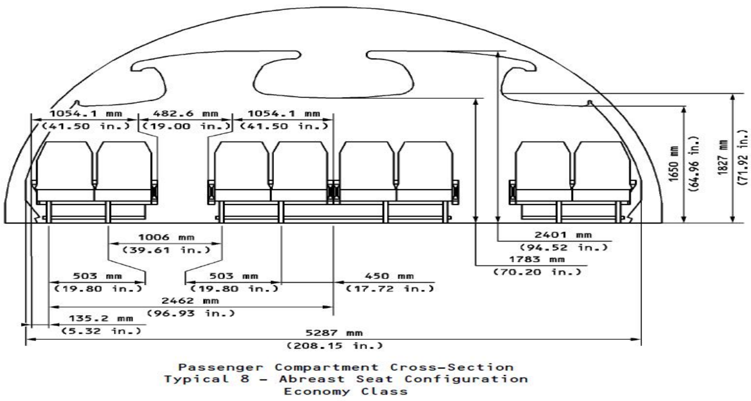

Figure1.1 A330-200 fuselage cross-section

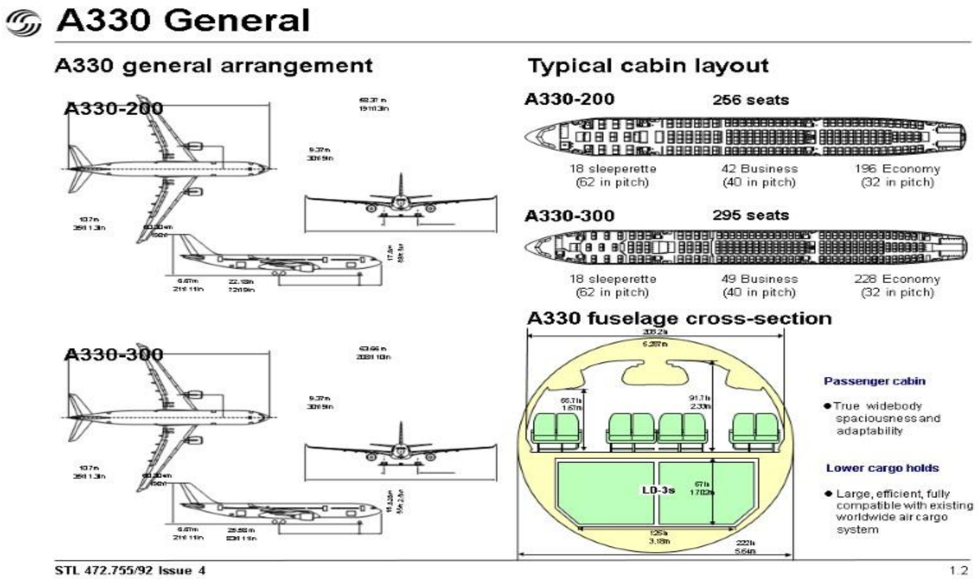

Figure 1.2 – General view and cabin layout of A330

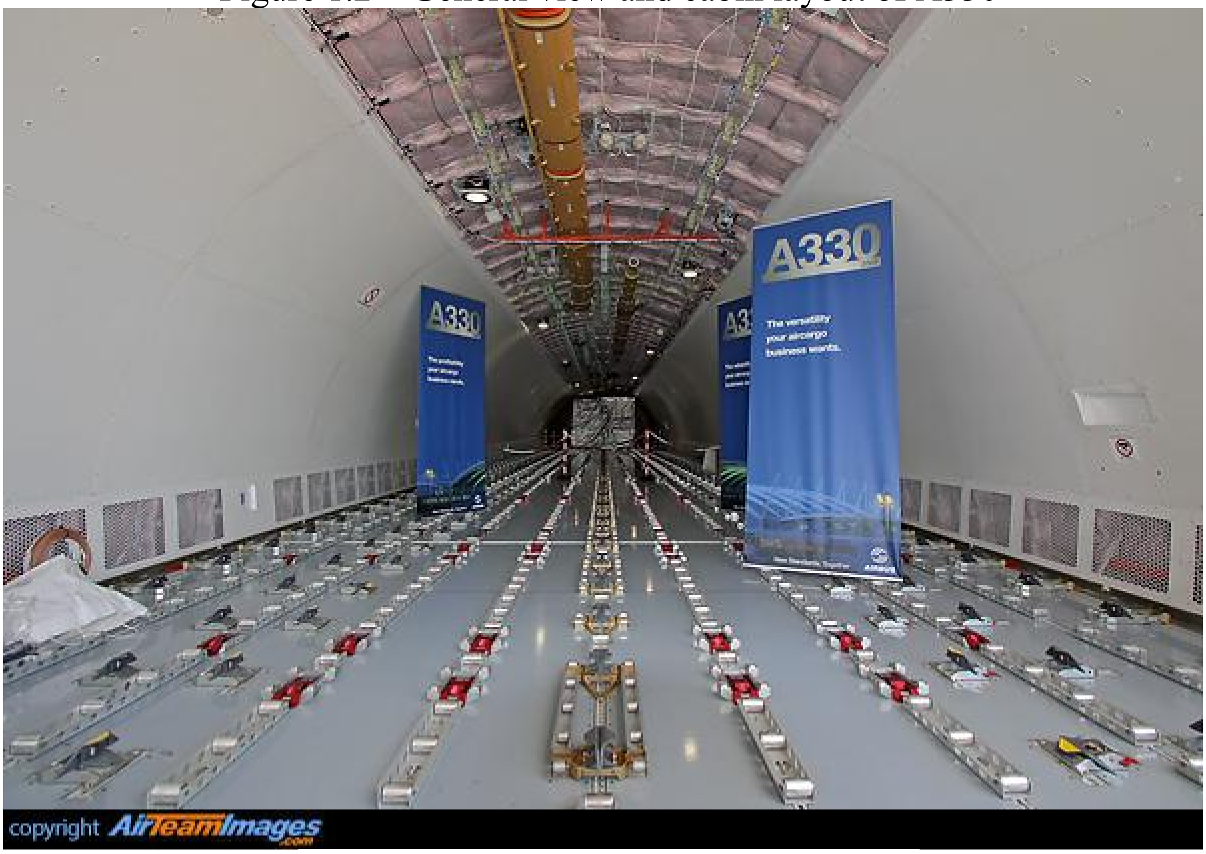

Figure 1.3 – Cargo compartment of A330

The TA9 was originally spec to accommodate 410 passengers in a single cabin and presented a larger lower cargo hold capacity, with five pallets or 16 LD3 containers in the forward section and four pallets or 14 LD3 containers in the rear section, twice the capacity of the L-1011 and DC-10, and extended the A300 by 8.46 meters.

1.2 Geometry calculations for the main parts of the aircraft

The layout of an aircraft includes the relative positions of the components and structures that make up it, as well as all types of loads (passengers, baggage, cargo, fuel, etc.). The choice of composition and aircraft parameters is based on a solution that aims to best meet operational requirements.

1.2.1. Wing geometry calculation

The geometric characteristics of the wing can be determined by taking the weight m_0 and the specific wing load P_0.

Full wing area with extensions is:

$$S_{wfull} = \frac{m_0 * g}{P_0} = 334m^2$$

Relative wing extensions area is 0

Wing area is:

$$S_w = \frac{m_0 * g}{P_0} = 334m^2$$

Wing span is:

$$l = \sqrt{S_w * \lambda_w} = 57.97m$$

Root chord is:

$$b_0 = \frac{2S_w * \eta_w}{(1+\eta_w) * l} = 8.64m$$

Tip chord is:

$$b_t = \frac{b_0}{\eta_w} = 2.88m$$

The forehead i-section determines the maximum width of the wing, which has a span equal to :

$$c_i = c_w * b_t = 0.32$$

On board chord for trapezoidal shaped wing is:

$$b_{ob} = b_0 * (1 - \frac{(\eta_w - 1) * D_f}{\eta_w * l_w}) = 8.08$$

The number and position of the longitudinal beams, as well as the position of the wing distribution, were determined in the selection of the wing power scheme.

The geometric method of averaging pneumatic strings is used to find the length of the mean aerodynamic chord(figure 2.1). Mean aerodynamic chord is equal: $b_{MAC} = 6.24m$

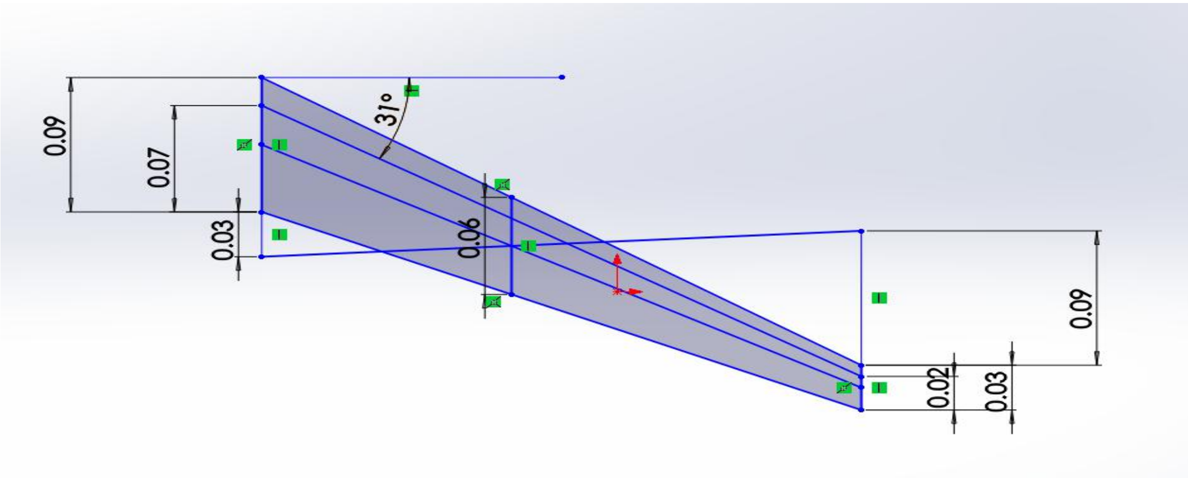

Figure 2.1. – Determination of mean aerodynamic chord

After determining the geometric characteristics of the wing, the aileron geometry and high-lift devices need to be estimated.

The aileron geometry parameters are determined in the next step:

Ailerons span:

$$l_{ai} = 0.375 * \frac{l_w}{2} = 10.87m$$

Aileron area:

$$S_{ail} = 0.065 * \frac{S_w}{2} = 10.86m^2$$

Increasing of l_{ail} and b_{ail} more than recommended values is not necessary and convenient. As the airfoil spacing is greater than a given value, the increase in the aileron coefficient decreases and the large lift device span decreases.

The tendency to reduce the relative wingspan and aileron area is present in third generation aircraft. So, l_{ail} = 10.87m. In this case for the transversal control of the airplane we use spoilers together with the ailerons. As a result, the span and area of high-lift devices may be increased, thereby improving the takeoff and landing characteristics of the aircraft.

Aerodynamic compensation of the aileron.

Axial $S_{axinail} \leq$ （0.25-0.28）S_{ail} =0.27*10.855=2.93m^2

Inner axial compensation

$$S_{inaxinail} = (0.3..0.31)\ S_{ail} = 0.88m^2$$

Area of ailerons trim tab.

For three engine airplane:

$$S_{tail} = (0.05 - 0.06) S_{ail} = 0.15\text{m}^2$$

Range of aileron deflection

Upward $\delta'_{ail} \geq 20^\circ$

Downward $\delta''_{ail} \geq 10^\circ$

In order to obtain the wing lift takeoff and landing coefficients, it is necessary to determine the wing high-lift device geometry parameters, assuming that in the previous calculations with the selected high-lift device rate and type of airfoil.

Before performing the following calculations, it is necessary to select the type of airfoil according to the airfoil catalog, specify the value of the lift coefficient, and determine the necessary increase of this coefficient for the exit of high-lift devices according to the formula: $\Delta C_{y\max} = (\frac{C_{y\max l}}{C_{y\max bw}})$.

Where is the necessary coefficient of lift of the wing in the landing configuration in the aircraft landing guarantee (it is determined during the selection of 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 – slats.

The effectiveness of high-lift equipment (C^*_{ymaxl}) rises proportionally to the increase in wingspan, served by high-lift equipment, so we need to obtain the maximum span of high-lift equipment($l_{hld} = l_w - D_f - 2l_{ail} - l_n$) due to the use of flight spoilers and the maximum reduction of the engine and landing gear nacelles.

In the selection of structural dynamics scheme, articulation scheme and kinematics scheme for large lift devices, it is necessary to draw on the statistics and experience of domestic and foreign aircraft construction. In most of the existing structural elements of high-lift equipment are powered by longitudinal beam structural solutions, which we need to take note of.

1.2.2 Fuselage layout

We need to start from the aerodynamic requirements (streamlining and cross-section) in order to choose the right fuselage shape and cross-section size

For subsonic passenger and cargo aircraft (V < 800km /h), the wave drag does not remain unaffected. So we need to select the frictional drag Cxf and profile drag Cxp from the condition table.

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:

$$l_{nfp} = 1.2 * 5.6 = 6.72\ m$$

In addition to aerodynamic requirements, strength and layout requirements need to be considered when selecting the section shape

To ensure minimum weight, the most convenient fuselage cross-section shape is a circular cross-section. In this case we have the minimum width of the fuselage skin. As a local case, we can use a combination of two or more vertical or horizontal circular sequences.

For cargo aircraft, aerodynamics is not very important for the choice of fuselage shape and the cross-sectional shape can be close to rectangular.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:

$$l_f = \lambda_f * D_f = 9 * 5.64 = 50.76\text{m}$$

Fuselage nose part aspect ratio is equal:

$$\lambda_{fnp} = \frac{l_{fnp}}{D_f} = 1.2$$

Length of the fuselage rear part is equal:

$$l_{frp} = \lambda_{\text{frp}} * D_f = 3.67 * 5.6 = 20.53m$$

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. Cabin height is one of the main parameters to be determined for the mid-section of an airliner.

For short range airplanes we may take the height as: h_1=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_1=1.9m; passage width b_p=0.6m; the distance from the window to the flour h_2=1m; luggage space h_3=0.9...1.3m.

I choose the next parameters:

Cabin height is equal:

$$H_{cab} = 1.48 + 0.17 B_{cab} = 1.48 + 0.17 * 5.28 = 2.38\text{m}$$

From a design point of view, the circular cross-section is convenient because in this case it is relatively the strongest and lightest. However, for the placement of passengers and cargo, this shape is not very convenient. In most cases, one of the most appropriate methods is to use a combination of two round crosses, or to have the fuselage oval in shape. It should be noted, however, that the oval shape is not very suitable in production, as the upper and lower panels will bend due to the additional pressure and therefore require additional bulkhead beams and other structural enlargements.

The steps of a normal bulkhead in fuselage construction are in the range of 360.. .500 mm range, depending on the type of fuselage and cabin class.

Considering designs with a diameter of less than 2800 mm, we do not use such a shape and we follow an intersecting circular section. In this case, the cabin floor is finished on a closed plane.

The windows are placed in a light row. The windows are round in shape and have a diameter of 300.. .400 mm, or rectangular with rounded corners. The steps of the windows correspond to the bulkhead steps and are 500... .510 mm. For economic salon with the scheme of allocation of seats in the one row (2+4+2) determine the appropriate width of the cabin

$$B_{cab} = n_{2chblock} * b_{2chblock} + b_{4chblock} + 2b_{aisle} + 2\delta = 1000*2 + 2000 + 2*550 + 2*90 = 5280\text{mm}$$

The length of passenger cabin is equal:

$$L_{cab} = L_1 + (n_{raws} - 1) * L_{seatpitch} + L_2 = 1200 + (30-1)*750 + 300 = 23250\text{mm}$$

1.2.3 Luggage compartment

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

The area of cargo compartment is defined:

$$S_{cargo} = \frac{M_{bag}}{0.4K} + \frac{M_{cargo\&mail}}{0.6K} = \frac{25*243}{0.4*600} + \frac{15*243}{0.6*600} = 34.4m^2$$

Cargo compartment volume is equal:

$$V_{cargo} = v * n_{pass} = 0.2*243 = 48.6m^3$$

Luggage compartment design similar to the prototype

1. 2.4 Galleys and buffets

International standards state that if the aircraft does a mixed layout, two courses must be provided. If the flight time is less than three hours, food should be distributed to passengers at this time, in which case cups of tea should be provided. Self-service or toilets cannot be used during the hour of flight time. Kitchen cabinets must be placed on the door, preferably with a separate door between the cockpit and the passengers or cargo. Refreshments and food should not be placed near toilets or attached to closets.

Volume of buffets(galleys) is equal:

$$V_{gally} = 0.1*243 = 24.3m^3$$

Area of buffets(galleys) is equal:

$$S_{galley} = \frac{V_{galley}}{H_{cab}} = \frac{24.3}{2.3776} = 10.22m^2$$

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.

1.2.5 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 passengers t <2 hours to 60 passengers.

The number of bathrooms for the selected aircraft is determined by the following formula:

$n_{lav} = 6$

Area of lavatory:

$S_{lav} = 1.5m^2$

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

1.2.6 Layout and calculation of basic parameters of tail unit

The selection of the tail unit arrangement is one of the important tasks of the aerodynamic layout. Its center of gravity should be placed in front of the focal point of the aircraft, this is for longitudinal stability to be guaranteed in case of overload, the distance between these points is related to the average value of the aerodynamic chord of the wing and the longitudinal stability rate is related to it.

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

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 in stable.Moving the focal point of the wing-fuselage combination rearward during the tail unit installation is in the normal aircraft design scheme..

The first method of finding the geometric parameters can be determined using the table.

The area of the pitot tail unit can be obtained from the following equation:

$$S_{VTU} = \frac{l_w * S_w}{L_{VTU}} A_{VTU} = \frac{334*57.97}{15.6}*0.07 = 86.88m^2$$

Area o horizontal tail unit is equal:

$$S_{HTU} = \frac{b_{MAC} * S_w}{L_{HTU}} * A_{HTU} = \frac{334*4.875}{2.5*6.24}*0.5 = 52.19m^2$$

Values L_{htu} and L_{vtu} depend on some factors. Above all, the swept-back and wing positions, the fuselage front and tail lengths, all affect their values, while aircraft stability and handling conditions affect their values..

Determination of the elevator area and direction:

Altitude elevator area:

$$S_{el} = 0.3 * S_{HTU} = 15.66m^2$$

Rudder area:

$$S_{rud} = 0.2 * S_{VTU} = 17.38m^2$$

Choose the area of aerodynamic balance.

0.3≤M≤0.6, S_{eb}=(0.22..0.25)S_{ea}, S_{rb}=(0.2..0.22)S_{rd}

The area of altitude elevator trim tab:

$$S_{te} = 0.08 * S_{el} = 1.25m^2$$

Area of rudder trim tab is equal:

$$S_{tr} = 0.06 * S_{rud} = 1.04m^2$$

Root chord of horizontal stabilizer is:

$$b_{0HTU} = \frac{2S_{HTU} * \eta_{HTU}}{(1+\eta_{HTU}) * l_{HTU}} = 5.018m$$

Tip chord of horizontal stabilizer is:

$$b_{tHTU} = \frac{b_{0HTU}}{\eta_{HTU}} = 1.67m$$

Root chord of vertical stabilizer is:

$$b_{0VTU} = \frac{2S_{VTU} * \eta_{VTU}}{(1+\eta_{VTU}) * l_{VTU}} = 8.35m$$

Tip chord of vertical stabilizer is:

$$b_{tVTU} = \frac{b_{0VTU}}{\eta_{VTU}} = 2.79m$$

1.2.7 Landing gear design

Since there is no general drawing of the aircraft, when the position of the center of gravity of the aircraft is determined, only the parameters of the landing gear part can be determined, which is the problem faced at the early stage of design.

Main wheel axel offset is:

$$e = 0.2673 * b_{MAC} = 0.2673 * 6.24 = 1.67m$$

The lift of the front gear is complex and usually occurs when the large wheel is offset axially, while the aircraft tail may drop when the small wheel is offset. Expression can find the axis distance of the landing gear:

$$B = 0.4526 * 50.76 = 22.97m$$

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

Front wheel axial offset will be equal:

$$d_{ng} = B - e = 21.31m$$

Wheel track is:

$$T = 0.6072 * B = 13.94m$$

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

Depending on the size, operating load and weight from takeoff can determine the wheels of the landing gear; for the front bracket, the dynamic load should also be taken into account.

The runway surface determines the type of pneumatic type and the pressure inside. Brakes are mounted on the main wheels, and brakes are sometimes used to mount on the front wheels.

The load on the wheels is given by the following equation:

K_g = 1.5...2.0 – dynamics coefficient.

Nose wheel load is equal:

$$P_{NLG} = \frac{(9.81 * e * k_g * m_0)}{(B * z)} = 141581.60N$$

Main wheel load is equal:

$$P_{MLG} = \frac{(9.81 * (B - e) * m_0)}{(B * n * z)} = 226017.04N$$

Table 2.1 – Aviation tires for designing aircraft

Main gear		Nose gear	
Tire size	Ply rating	Tire size	Ply rating
940x 300	18	890x220 mm	12

1.2.8 Choice and description of power plant

General Electric's CF6, F103 being its U.S. military designation, is a family of high-bypass turbofan engines produced by General Aviation. CF6 is based on the TF39, the first high power, high-culvertibility jet engine, powering a wide range of civilian aircraft.

The Pratt & Whitney PW4000 is a family of high-bypass turbofan aircraft engines produced by Pratt & Whitney as a successor to the JT9D. st was operational in April 1984, certified by the FAA in July 1986, and introduced in June 1987. Thrust range of 50,000 to 99,040 lbf (222 to 441 kN) for many wide-body airliners

The Rolls-Royce Trent 700 is a turbofan engine family. It is derived from the Rolls-Royce RB211, a member of the Trent engine family, and is designed for use on the Airbus A330 family of aircraft

Table 2.2 – Examples of application

Model	Thrust	Bypass ratio	Dry weight
The General Electric CF6	299.7kN	5–5.1	5,092 kg
The Pratt & Whitney PW4000	287-311 kN	4.9:1	5,851 kg
The Rolls-Royce Trent 700	234.7KN	5.0	4785kg

1.3.Brief description of the main parts of the aircraft

The aircraft is fitted with a high span-to-skin ratio swept-back wing based on a new supercritical wing type. The fuselage is circular in cross-section. Conventional tail with adjustable fuselage vertical tail. Aerodynamic balancing devices are mounted on the rudder and elevator.

1.3.1Fuselage

Based on the Airbus A300-600 fuselage, this aircraft has the same fuselage, exterior and cabin widths: 5.64 meters and 5.26 meters, and has many common components. Business Class 2-2-2 6-seater and Economy Class 2-4-2 8-seater are used as typical seating arrangements. When necessary, the Honeywell 331-350C Auxiliary Power Unit (APU) will provide aerodynamic and electrical power to the aircraft.

Glass cockpit flight deck layout This aircraft shares one with the A320 and A340 and uses electronic instrument displays instead of mechanical instruments.Sidestick controls, six primary displays, an electronic flight instrument system (EFIS) and electronic aircraft central display (ECAM), including navigation and flight displays were mounted on the flight deck, unlike the traditional control yoke... In addition to the flight deck, the plane uses the flight control system common to the A320 family, A340, A350 and A380. Three primary flight control systems and a flight limit protection system, as well as two secondary flight control systems are installed on the aircraft. The limit protection system is to prevent maneuvers from exceeding the aerodynamic and structural limits of the aircraft.

1.3.2Wing

The aircraft has a low-wing monoplane fuselage with almost identical wings to the A340-200/300. The wing later extends to 57.97 m. On the aircraft, the engine is mounted on an inboard hanger; the wing is equipped with wingtip winglets.

Aircraft performance can be improved by 5% to 7% due to the use of winglets. The main principle is to reduce the powerful vortex that is generated behind the wingtip when the aircraft cuts through the air. This is what usually happens when the low pressure airflow over the wing and the high pressure airflow under the wing meet at the wingtip. The negative effect of this is that the vortex creates drag that slows the aircraft down and requires increased thrust to counteract it, thus increasing fuel burn. This is something the designers did not want. So with clever aeronautical design winglets can alter and significantly reduce the vortex, allowing the aircraft to consume less fuel to maintain the same speed.

In order to achieve a large span and high span-to-chord ratio without significant weight loss, a wing swept back of 30 degrees is used, along with other design features that allow a maximum operating Mach number of 0.86. The thick chord ratio of the wing is 11.8% or 12.8%. The thick chord ratio varies from 9.4 to 13 percent in jetliners. Each wing is 2.74 meters (9 feet 0 inches) high, rather than the wingtip fence of earlier Airbus aircraft.

In order to allow the aircraft to incorporate the aerodynamic characteristics developed for the former, the wing design had commonality with the A340's wing. The wing was designed with a 56-meter (180-foot) wingspan, which was later expanded to 57.97 meters, with a wingspan similar to that of the larger Boeing 747-200 aircraft, but with a 35 percent reduction in wing area.

Structurally, the wing consists of three parts: the centre, the caisson and tail part. It also has mechanized functions (flaps, ailerons, interceptors) that significantly improve the aircraft's take-off and landing characteristics and manoeuvrability.

The structure part of the wing is the caisson 3, 5, which receives the main loads acting on the wing. The sock and tail of the wing perceive only local air loads and transfer them to the caisson.

The wing has a relatively small distance from the ground, resulting in an increase in the lift factor due to the influence of the ground, thereby improving the takeoff and landing characteristics.

1.3.3Tail unit

The tail is swept, traditional and consists of vertical and horizontal plumage.

Vertical plumage includes stabilizer, fin and rudder, horizontal plumage includes stabilizer and elevator.

Composite materials for tailplane, rudder, elevator, horizontal tailplane used as fuel tanks, flaps, ailerons and spoilers; they account for 10% of the weight of the structure

The vertical and horizontal plumage profile is symmetrical. The metric profile can maintain the same aerodynamic load characteristics with less drag during rudder deflection in different directions.

The relative thickness of the horizontal airfoil profile is increased relative to the horizontal airfoil profile to reduce the weight of the fins under the bearing force for both the vertical and horizontal airfoil profiles.

1.3.4Crew cabin

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

The application of conical windshields with radio alarms in the crew cabin provides a good protection for the pilot, meeting the requirements of flight operations in the expected conditions. There are manual and automatic controls possible from anywhere for the pilot.

Placement of devices and light signaling devices on a control panel of pilots is executed according to requirements of standards of the flight airworthiness. Place a control panel apex in the most accessible area and place quick-use command radio control panels and automated control systems.

The cabin system top control panel houses the fuel, hydraulic, power, anti-freeze, air conditioning, engine and APU start, fire suppression switch and warning alarm system panels.

The central control panel not only houses the traditional control lever engines, but also the navigation and landing equipment panels

1.3.5Passenger furnishing

Passengers provide the aircraft with the necessary conveniences for the aircraft. It includes adjustable pilot seats, flight attendance seats and passenger seats; light filters and light protection blinds and toilets.

A toilet and galley are placed between the crew cabin and the passenger cabin (toilet on the left panel and galley on the right panel). The toilet has an area of 1 square metre.

In the toilet there is a water tank with water and technical fluids. A vacuum flush toilet has been built into the toilet. There are three first aid kits on board (one in the crew compartment, one included in the structure of the crash equipment and one in the tail section).

The aircraft is also equipped with appropriate emergency equipment, including ropes, oxygen masks, smoke masks, oxygen units, manual fire extinguishers, first aid kits, axes, emergency radios and radio beacons, light markings for evacuation routes, emergency lighting, and "EXIT" signs near each emergency exit, as well as crew, passenger, and observer life jackets, and crew and passenger lifeboats.

1.3.6 Control system

The flight control system allows the aircraft to maintain the necessary attitude during flight. There are movable surfaces on both the wings and the wing. The primary flight control system moves the aircraft around three axes: lateral, longitudinal and vertical, including aileron, elevator and rudder. Secondary flight control systems improve the lift and maneuverability of the aircraft and include leading edge devices, trailing edge flaps, spoilers and speed brakes, horizontal stabilizers, etc..

1.3.7 Landing gear

1.General

The aircraft has:

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

-One forward landing gear (NLG) with two-wheel assembly and associated doors.

The main landing gear is located under each wing and is retracted toward the fuselage center line side.

The nose landing gear is stowed forward into the fuselage compartment under the cockpit. The landing gear and landing gear door retractions are hydraulically and mechanically operated. Controls, sequences and indications are electrical. In abnormal operation, the landing gear can be extended by gravity.

2. Main Landing Gear and Doors

Each MLG has a leg components and a four-wheel bogie beam. The legs include a shortening mechanism, a bogie pitch adjuster and a hydraulic pneumatic shock absorber. In flight, when the MLG extension, bogie by articulated connecting rod and pitch adjuster in position behind the low (rear). When MLG fully extended, fold the base through the locking lever (by bottom lock actuator operation) mechanical lock. Each MLG pod has the following doors:

-hydraulically operated main doors.

-mechanically hinged doors.

-Rectifier doors on MLG legs

When the main landing gear is retracted, all doors are closed. When the main landing gear is lengthened, the main doors close and the hinged doors remain open. When the aircraft is on the ground, a manually operated mechanism (maintenance personnel) allows the main doors to open to access the MLG compartment

3. Nose Landing Gear and Doors

It includes a twin axle assembly and an oil and gas shock absorber. The NLG is supported longitudinally by a two-piece towbar. When the NLG is fully extended, the towbar is mechanically locked by the chain.

Each NLG cabin has the following doors.

- Two hydraulically operated FWD doors.
- Two mechanically operated AFT doors.
- A fixed fairing door on the NLG leg

When the NLG retracts, all doors close. When the NLG is extended, the FWD door closes and the AFT door remains open. A door opening mechanism allows the

FWD door to open on the ground for access to the NLG cabin.

1.4 Center of gravity calculation

1.4.1 Trim-sheet of the equipped wing

The quality of the equipped wing includes the quality of its structure, the quality of the equipment placed on the wing and the quality of the fuel. Regardless of where they are mounted (wing or fuselage), the main landing gear and front gears are included in the quality register for equipping the wing. The mass register contains the names of objects, the masses themselves, and their barycenter coordinates. The origin of the given coordinate of the center of mass is selected by the projection of the head point of the mean aerodynamic string (MAC) of the surface XOY. The positive meaning of the coordinates of the center of mass is accepted as the terminal portion of the aircraft.

The list of examples of aircraft whose engines are situated under the wings and whose mass objects include the designations given in Table 3.1. The following equation defines the coordinates of the power center of the equipped wing:

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

Table 3.1 - Trim sheet of equipped wing

		Mass			
№	Object name	relative mass	real mass/kg	C.G coordinates Xi, м	Moment of mass/kgm
1	wing	0.12619	25080.01	2.81	70424.67
2	fuel system	0.0126	2504.22	2.81	7031.86
3	Flight control system, 30%	0.0012	238.50	3.74	892.94
4	electrical equipment, 10%	0.00269	534.63	0.62	333.61
5	anti-ice system , 50%	0.0087	1729.11	0.62	1078.96
6	hydraulic systems , 70%	0.00854	1697.31	3.74	6354.72

	1	2	3	4	5
7	Engines (-fuel system)	0.07754	15410.92	-6.34	-97782.29
	equipped wing without landing gear and fuel	0.22486	44690.48	-0.42	-18697.39
8	nose landing gear(10-15%)	0.0033	650.40	-23.27	-15132.25
9	main landing gear(85-90%)	0.030177	5997.62	3.43	20583.83
10	fuel	0.39618	78740.00	2.81	221101.87
	Total	0.65457	130078.48	1.60	207856.06

1.4.2 Trim-sheet of the equipped fuselage

The projection of the head of the fuselage on the horizontal axis is usually chosen as the origin of the coordinates. The structural part of the fuselage is given for the X-axis.Examples of AC objects for engines mounted under the wing are listed in Table 3.2

The CG coordinates of fuselage can be determined from the formula:

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

After the C.G. of the fully equipped wing and fuselage have been determined by us, the moment balance equations with respect to the head of the fuselage have also been constructed:

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

The position of the leading edge of the wing MAC relative to the fuselage is determined from here and is defined as the Xmac value in Eq.

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

where $\boldsymbol{m_0}$ – aircraft takeoff mass, kg; $\boldsymbol{m_f}$ – mass of fully equipped fuselage, kg;

m_w – mass of fully equipped wing, kg; The distance from the leading edge of the MAC to the C.G. point is defined as C , which is mainly determined by the designer

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

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

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

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

at X= 45° C = (0,32...0,36) B_{MAC}

X_{MAC}=24.30m

C_{mac}=6.24m

L_f=50.4m

Table 3.2 – Trim sheet of equipped fuselage

		Mass			
№		relative mass	real mass	C.G coordinates Xi, м	Moment of mass
1	fuselage	0.07769	15440.73	25.2	389106.45
2	horizontal tail	0.00932	1852.33	46.68	86466.83
3	vertical tail	0.00962	1911.96	40.237	76931.36
4	navigation equipment	0.0036	715.49	6.376	4561.98
5	radio equipment	0.0018	357.74	1.234	441.46
6	radar	0.0024	477.00	8.376	3995.31
7	instrument panel	0.0042	834.74	1.234	1030.07
8	Flight control system 70%	0.0028	556.49	25.2	14023.66
9	hydraulic system 30%	0.00366	727.42	35.28	25663.30
10	anti ice system, 25%	0.00435	864.55	40.32	34858.81
	airconditioning system, 25%	0.00435	864.55	25.2	21786.76
11	electrical equipment, 90%	0.02421	4811.69	25.2	121254.56
12	lining and insulation	0.0057	1132.86	25.2	28548.16
13	Load devices equipment	0.0101	2007.35	26.67	53536.15

	1	2	3	4	5
14	Not typical equipment	0.0021	417.37	2	834.74
15	Additional equipment (emergency equipment)	0.0069	1371.36	2	2742.72
16	Operational items	0.01812	3601.31	1.65	5942.17
17	Furnishing:	0.0101	2007.35	28.39226	56993.34
	lavatory1,8%	0.00081	160.59	3.5	562.06
	lavatory2,8%	0.00081	160.59	32.5	5219.12
	lavatory3,8%	0.00081	160.59	32.5	5219.12
	lavatory4, 8%	0.00081	160.59	48.13	7728.48
	lavatory5, 8%	0.00081	160.59	48.13	7728.48
	galley 1, 30%	0.00303	602.21	5.14	3095.94
	galley 2, 30%	0.00303	602.21	45.57	27440.14
18	Passenger equipment:	0.0097	1927.86	38.05	73352.98
	passenger seats (economy class) 1 seat/block of 2/block of 3 6-8kg/12-15kg/18-20kg	0.0072	1440	31.879	45905.76
	seats of flight attendances	0.0020	390.4	4.113	1605.72
	seats of pilots	0.00049	97.6	2.057	200.76
19	equipped fuselage without payload	0.21072	41880.18	23.93	1002070.81
21	on board meal	0.013283	2639.97	50.707	133864.94
22	Baggage, cargo, mail	0.060	11879.86	26.67	316835.96
23	Passengers	0.053	10559.88	38.049	401792.83
24	crew	0.0066	1319.98	2.26	2983.17
	TOTAL	0.34	68279.88	27.20	1857547.71

1.4.3 Calculation of center of gravity positioning variants

The list of mass objects used for the calculation of the center of gravity variable and the options for the calculation of the center of gravity are given and completed by the following two tables.

Table 3.3 – Calculation of C.G. positioning variants

Calculation of the C.G. positioning variants			
Name	Mass, Kg	Coordinate	Mass moment
object	m_i	C.G., M	Kg.m
equipped wing (without fuel and landing gear)	44690.48	23.88	1067199.41
Nose landing gear (extended)	650.40	2.03	1321.73
main landing gear (extended)	5997.62	27.73	166314.98
fuel/fuel reserve	78740.00	27.61	2173709.40
equipped fuselage (without payload)	41880.18	23.93	1002070.82
passengers of economy class	10559.88	38.05	401792.83
baggage，Cargo, mail	11879.68	24.30	288654.58
crew	1710.38	4.11	7034.81
nose landing gear (retracted)	650.40	1.03	671.32
main landing gear (retracted)	5997.62	27.73	166314.98
reserve fuel	72868.97	27.11	1975198.65
Total	268977.57	26.33	7083297.20

Table 3.4 – Airplanes C.G. position variants

Variants of the loading	Mass, kg	Moment of the mass, kg*m	Center of mass, m	Centering
take off mass (L.G. extended)	198748	5108098.55	25.70	0.2249
take off mass (L.G. retracted)	198748	5107448.15	25.70	0.2243
landing weight (LG extended)	190237.59	4909587.80	25.81	0.24

1	2	3	4	5
Ferry version	173669.04	4417000.745	25.43	0.18
Parking version	93218.67	2236906.933	25.50	0.19
Variants of the loading	Mass, kg	Moment of the mass, kg*m	Center of mass, m	Centering

1.5 Conclusion to the project part

In the preliminary design, the aircraft should meet the purpose of use and its geometrical features should provide the necessary aerodynamic performance.

During the design process, I determined the main geometric parameters of the wings, fuselage, tail, control surfaces and landing gear. In addition, the layout of the cargo hold was determined. All this work fulfilled the requirements of a short-range freighter.

For the centre of gravity of the aircraft, the most forward centre of gravity position is the leading edge of the main aerodynamic chord and the most rearward centre of gravity position is the leading edge of the main aerodynamic chord. The final centre of gravity position for equipped aircraft is the leading edge of the main aerodynamic chord. This fulfils the requirements for a long-range passenger aircraft.

The design aircraft is based on the chosen prototype with some geometrical parameters refined to meet the requirements of modern passenger aircraft. In the future, this airliner will be competitive on the market

2. Development of landing gear system

2.1. **Description and application of the Oleo strut**

The landing gear must be capable of absorbing the shock applied to the structure during the landing operation (mainly during the touchdown phase). Some light, ultralight, small and home-built aircraft, most helicopters, plus sailplanes, use rigid shafts or solid springs and rely entirely on tyres and solid springs for shock absorption. Although the tyres themselves provide some shock absorption through deformation, for medium/large aircraft the shock absorption requirements are higher than what the tyres can provide. Solid springs tend to be fairly simple in design and are used in many light aircraft.

Oleo struts are used on the landing gear of many large aircraft and many small aircraft as an aerodynamic hydrodynamic shock absorber. Vertical vibrations are dampened by the fact that this world buffers the impact during landing. Since the aircraft can bounce during landing and cause loss of control, this tendency should not be present in the design of the landing gear. The steel coil spring stores the energy of the impact on landing and then releases it, while the oiled strut absorbs this energy and reduces bounce. When the strut is compressed, the spring rate increases sharply due to the compressed air, and the bouncing motion is inhibited by the viscosity of the oil.

The original design of the oil and gas shock-absorbing strut was patented by the British manufacturing conglomerate Vickers Armstrong in 1915. It was derived from the design of the recuperation device for Vickers guns, which controlled recoil by forcing oil through precisely sized holes. The French aircraft company Breguet Aviation first used Vickers' oleo struts in an aircraft.[15]

2.1.2. Operation and Installation of Oleo strut

An internal metal tube or piston forms the Oleo strut, which is connected by an axle to an external (or upper) metal tube or cylinder on the body and can be moved up and down.The gas fills the cavity inside the strut and piston (usually nitrogen, sometimes air - especially in light aircraft) and the oil (usually hydraulic oil), dividing it into two chambers, communicating through a small hole

A cross-section of the two cylinders, if observed, reveals that the hydraulic oil is filled at the bottom of the cylinder. The nitrogen is filled in the top cylinder and there is a small hole known as the orifice., connecting the two

Compressed gas in the cylinders to support the weight of the aircraft, this is the case when the aircraft is stationary on the ground, during landing, or when the piston slides up and down as the aircraft glides over bumps. To get the action of the spring, this movement compresses the gas and forces the oil through the orifice and the damper acts.. In order to provide greater resistance as the piston moves with increased strut compression, tapered rods are used in some designs to vary the size of the orifice as the piston moves. In addition, check valves are sometimes used to uncover more of the orifice, giving less damping on compression than on rebound. Part of the accumulated kinetic energy is usually converted into thermal energy to absorb and dissipate the shock load, a characteristic of oil-based pillars..

Pneumatic systems such as oleo struts usually have a long operational life and are not unusually complex for maintenance purposes. Due to its less likely to cause corrosion, Nitrogen is often used as a filler gas rather than air. O-rings or similar elastic seals are used to seal various parts of the branch pipe. In addition to this, scraping rings are used to prevent dirt and grit adhering to the piston from entering the branch pipe..

2.1.3. Principal of oleo struts operation

A cylinder and a piston are present in the oleo strut and the combination of a gas and a hydraulic fluid in these two chambers is used to absorb and dissipate the impact loads.The cylinder on the aircraft is fixed to the aircraft by the landing gear and the lower piston - attached to the axle on which the wheels are mounted - moves up and down in the upper cylinder.

The remaining space in the upper cylinder is filled with dry air or nitrogen, while the hydraulic oil is filled in the lower chamber. These two chambers are separated by an orifice plate which allows the hydraulic fluid to flow between the lower and upper chambers. Bearings maintain alignment and smooth movement between the piston and cylinder, and seals prevent leakage of hydraulic oil.

When the aircraft lands, the piston moves upwards into the cylinder, forcing the hydraulic fluid through the orifice into the upper chamber. The gas in the upper chamber acts like a spring and is compressed by the hydraulic fluid to absorb the shock of landing and the bumps in taxiing. During backlash, this causes the rod to extend, as the gas expands and forces the hydraulic fluid back into the lower chamber and causes the piston to fall back out of the cylinder. [16]The movement of the orifice generates heat due to the compression of the gas and the passage of the liquid, which is then transferred to the body and atmosphere through the struts by convection and conduction..

The size of the orifice controls the rate at which the hydraulic fluid enters and leaves the upper chamber, and the resulting compression and expansion of the gas.. The hydraulic oil, which is restricted by the orifice, therefore acts as a restraint to the piston movement during damping and recoil.

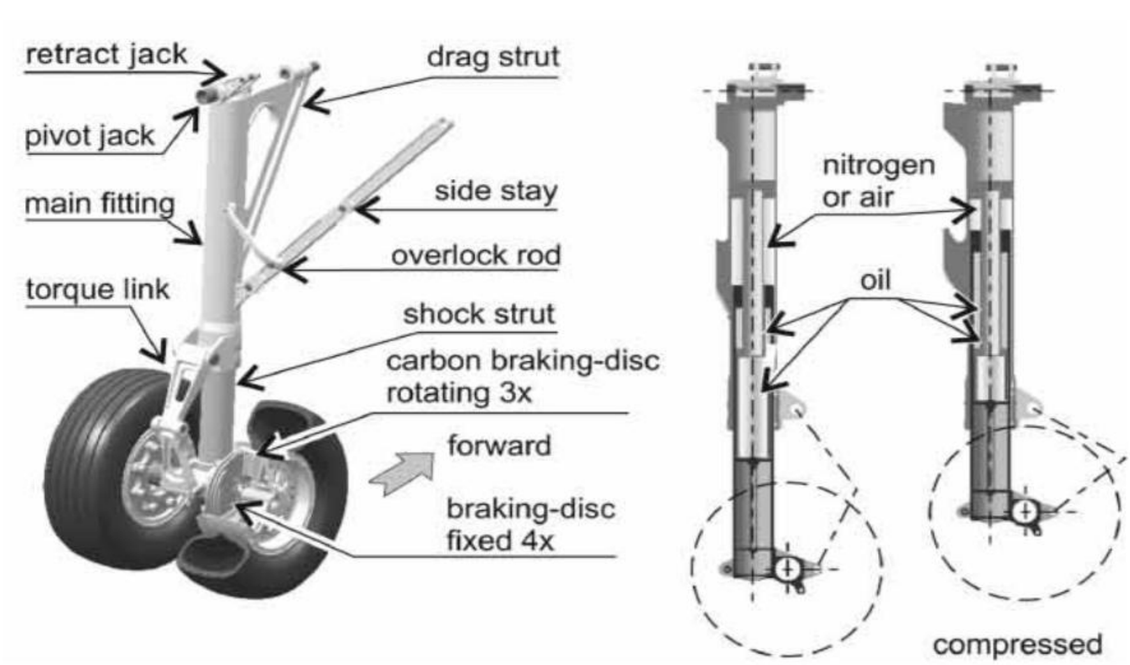

Figure 2.1. showing some of the main components of the left main landing gear of an Embraer EMB 190 (left) and the uncompressed and compressed states of its oleo shock strut (right).[15]

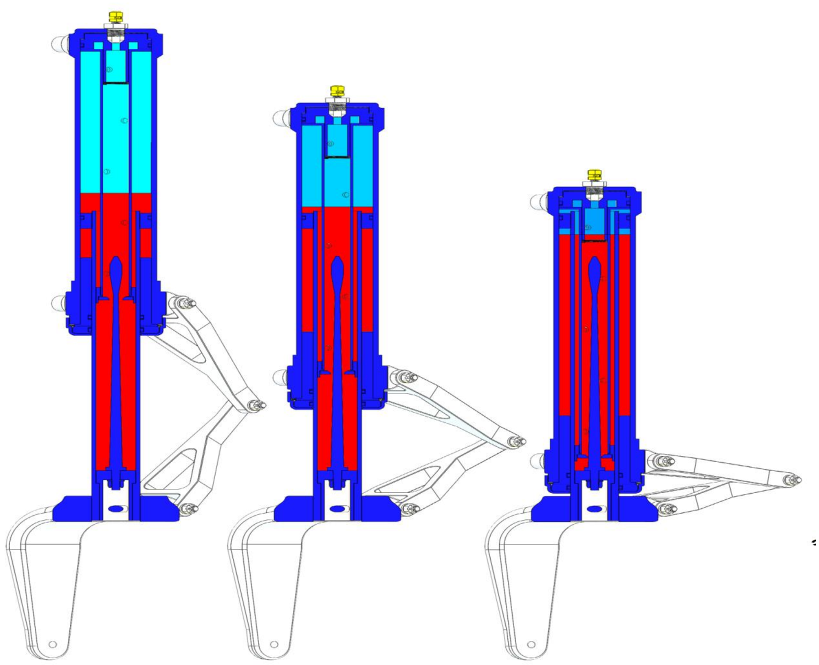

Figure2.2. illustrating the interaction between the gas (light blue) and hydraulic fluid (red) in an oleo strut during compression of the strut[15]

2.2. Design consideration

The compression ratio (the ratio of the strut pressure in the static position divided by the strut pressure in the extended position), as well as the load, stroke and pressure in the extended, static and compressed positions are all important design parameters for Oleo struts and need to be designed around these parameters

The sink rate of the aircraft, the load factor of the landing gear and the travel of the struts all need to be taken into account as important considerations when designing Oleo struts.The sink rate describes the vertical speed of the aircraft during landing. A typical sink speed for a transport aircraft is 10 ft/sec at the design landing weight.

The maximum load that can be accepted by the damping struts is defined as the landing gear load factor, which can be obtained by adding the static and dynamic reaction loads and dividing by the static load. Load factors vary between aircraft types, with typical landing gear load factors ranging from 0.75 to 1.5 for large transport aircraft and up to 5.0 for fighter aircraft[13].

The stroke consists of four processes, namely the strut stroke, the distance the piston travels, the wheel stroke, and the vertical distance the wheel travels. Some designs use a lever approach where the strut stroke is smaller than the wheel stroke to minimize the storage space required for the landing gear.

The distance from the static position to the fully compressed position as a percentage of the total piston stroke varies considerably between aircraft types, from single-digit percentages to nearly 50%..

Hydraulic fluids used in hydraulic struts are usually required to meet standards that specify minimum performance criteria, such as

MIL-PRF-5606 for mineral oil based hydraulic fluids.

MIL-PRF-83282 for synthetic hydrocarbon-based hydraulic fluids with better fire resistance than MIL-PRF-5606, or

MIL-PRF-87257 for synthetic hydrocarbon-based hydraulic fluids with better low-temperature viscosity performance than MIL-PRF-83282.[13]

Figure 2.3.The white oleo-pneumatic shock strut cylinder is clearly visible in this image of part of one of two main landing gear legs for the Boeing 787.

2.3. Shock absorber examination calculation

A sample shock absorber was studied to better understand the problem and how to use the combined approach. A static pressure of 1600 psi and a stroke of 22 inches are two basic figures for the sample shock absorber.The first step is to determine which compression ratio to use, which has a positive impact on the selection of a favourable shock absorber.

When this theory is used, the isothermal method from the fully extended point to the resting point and the fusion method from the resting point to the fully compressed point are best used. Thus, the following relationship is obtained by us.

The ratio of the pressure under one condition divided by the pressure under the other condition is defined as the compression ratio. Another case of pressure, for example, fully compressed and static.Typically, there are two compression ratios to be considered, they are.

The first ratio is fully extended to a static state and the other is static to fully compressed. As for larger aircraft, the following ratios can be used[18]：

Static to extended case(r_{sb})：4：1

Compressed to static case (r_{cs})：3：1

2.3.1.Isotherm calculations

First, let's consider isothermal calculations

Total stroke(S)=558.8mm(22 in),

static force(F_s)=19844.56kg(43750 lb),

static pressure(P_s)=8274000pa（1200psi），

Then ;

$P_1 = P_B = \frac{1}{r_{sb}} * P_s = \frac{1}{4} * 1200 = 300$ psi=2068500pa

$P_2 = P_s = 1200$ psi=8274000pa

$A_u = \frac{F_s}{P_s} = \frac{37500}{1200} = 31.25\text{in}^2$ =20161.25mm^2

Displacement volume(D)= $A_u * S = 31.25 * 22 = 687.5\text{in}^3$ =11266106.5mm^3

The standard symbols for shock strut dimensions use the subscript 1 for the fully extended position, 2 for the static position and 3 for the compressed position.

$V_1 - V_3 = D$

According to the ideal gas equation of state

$$P_1V_1 = P_3V_3 = const$$

$$V_1 = \frac{P_3(V_1 - D)}{P_1} = 750\text{in}^3\text{=12290298mm}^3$$

$$V_3 = V_1 - D = 62.5\text{in}^3\text{=1024191.5mm}^3$$

$$V_2 = \frac{P_1V_1}{P_2} = 187.5\text{in}^3\text{=3027574.5mm}^3$$

After sorting and simplifying we end up with the following data：

$$P_1 = 2068500\text{pa}，V_1 = 12290298\text{mm}^3$$

$$P_2 = 8274000\text{pa}, V_2 = 3027574.5\text{mm}^3$$

$$P_3 = 24822000\text{pa}, V_3 = 1024191.5\text{mm}^3$$

This equation $P_x = \frac{P_1V_1}{V_1 - A_uS_x}$ can then be used to find the pressure at any position，

where S_x means the stroke at point x and $S_{extend} < S_x < S_{static}$;and the corresponding volume can be found according to the ideal gas equation $P_x = \frac{P_1 V_1}{V_x}$.

2.3.2.Polytropic calculation

Considering that the initial pressure is the same in addition to the same volume factor, the polytropic state can be compared with the isothermal state; thus

$$V_1 = 750\text{in}^3 = 12290250\text{mm}^3$$
$$V_3 = 62.5\text{in}^3 = 1024187.5\text{mm}^3$$
$$P_1 = 300\text{psi} = 2068500\text{pa}$$

In the polytropic process, based on the fact that PV^n is a constant value, we can use this equation $P_x = P_1(\frac{V_1}{V_1 - A_u S_x})^n$ to derive the pressure at any point,where $S_{static} < S_x < S_{compress}$, To better understand this equation let's take an example, for example if we want to find the pressure value of P_3 , and we know that the stroke S is equal to 22in,the pressure value is in the polytropic compressed state[18]

$$. P_3 = P_1(\frac{V_1}{V_1 - AS_x})^n = 300*(\frac{750}{750-31.25*22})^{1.35} = 8590.45\text{psi} = 59231152.75\text{pa}$$

Note:For normal ground handling, when compression is low and the process is isothermal, n=1, whereas for dynamic (fast) compression situations, such as high compression for landing impacts, and corresponding to multivariate processes, n>1. In this process, either n=1.1 or n=1.35 can be considered, the former being used for gas and oil separation and the latter for mixing during compression

We can thus conclude:

$$F_{poly} = F_x, n > 1$$
$$F_{iso} = F_x, n = 1$$

One thing to note is the maximum pressure (pressure at full pressure) in the polytropic mode. For the polytropic method to be the basis of the design, provided that the pressure is less than the allowable pressure at that point.[18].

According to MIL-L-8552[19], the distance between the outer ends of the bearings should be no less than 2.75 times the outer diameter (D) of the internal cylinder/piston.The minimum piston length is therefore

$$L_{pist} = S + 2.75D$$

Where

$$D = \sqrt{\frac{4A}{\pi}}$$

And in our case $D = 6.31in = 160.27\text{mm}$,so $L_{pist} = 39.35\text{in} = 999.49\text{mm}$

The 16% expansion map was used and at the fully compressed position of 3.52 inches was estimated to be the static position for switching from the isotherm to the polytropic state.

2.3.3.The combined calculation (isotherm and polytropic state)

It should be noted that the pressure P_3 needs to be less than 6000psi at full compression to better prevent leakage.To avoid frictional adhesion of the piston to the cylinder wall and to prevent seal leakage, in this case the P1 and P3 values should be checked to ensure that the former is greater than 413700pa(60psi) and the latter less than 41370000pa (6000psi).As the table shows, the P_3 value is indeed less than 41370000pa(6000psi).

The results for the damper sample is shown in Table 2.1

Table2. 1 Calculations of isothermal and polytropic compression

Stroke/mm	V/mm³	P_{iso}/pa	P_{poly}/pa	P_{combi}/pa	F/N
0	12290250	2068500	2068500	2068500	41673.77
50.8	11266062.5	2256545.46	2326323.36	2256545.455	45462.29
101.6	10241875	2482200	2645758.55	2482200	50008.52
152.4	9217687.5	2758000	3050161.39	2758000	55565.02
203.2	8193500	3102750	3575845.33	3102750	62510.65
254	7169312.5	3546000	4282208.94	3546000	71440.74
304.8	6145125	4137000	5272857.32	4137000	83347.53

1	2	3	4	5	6
355.6	5120937.5	4964400	6744359.34	4964400	100017.04
406.4	4096750	6205500	9115263.32	6205500	125021.30
457.2	3072562.5	8274000	13441152.65	8274000	166695.06
469.392	2826757.5	8993478.26	15042601.36	8993478.26	181190.28
508	2048375	12411000	23235911.48	14303381.3	288168.12
558.8	1024187.5	24822000	59231155.82	36461053.29	734575.47

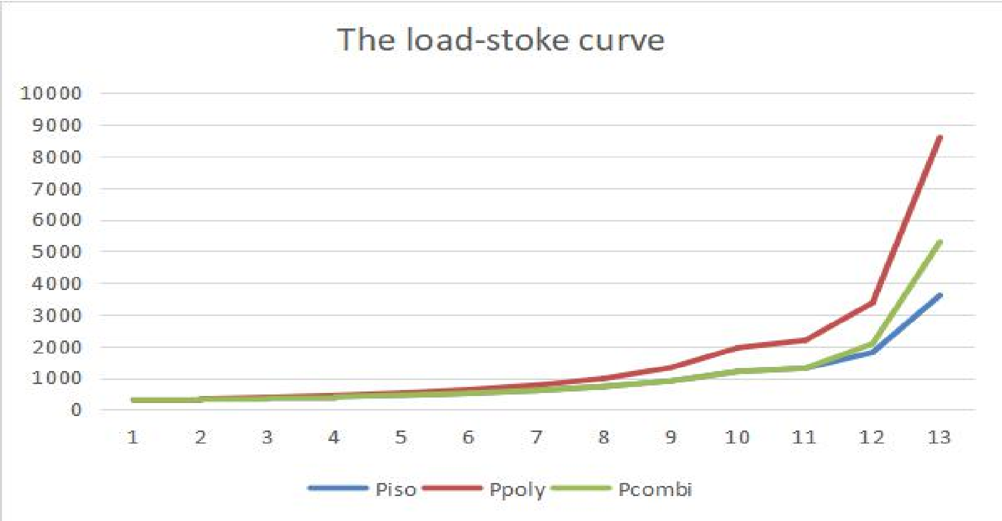

Figure 2.4 The load-stroke curve

2.4. Landing gear brake cooling system

According to one embodiment, an apparatus for an aircraft in flight equipped with at least one cooled landing gear brake is described. The apparatus comprises an air handling assembly coupled to the aircraft. At least one air handling assembly connected to the aircraft is included in the air handling assembly.. The appliance also includes an air delivery assembly for air connection to the air handler.. The air delivery assembly includes at least one nozzle generating an air pressure differential on the landing gear brake, due to the nozzle being configured to direct air into a first space adjacent to the first side of the landing gear brake.[20].

Here, a cooling system will be presented, as shown in the picture, a fan wheel kit and motor fan axle kit from SAFRAN.

Figure 2.5 Fan Wheel Kit RU1702A04

Figure 2.6Motor Fan Axle Kit

Its parameters are specified as follows

- Weight (kg): 2.75
- Noise (dBA):
- Acoustic pressure input: NA
- Acoustic pressure output: 96
- Radiated acoustic pressure: NA
- Current (A): 2.5
- Flow rate (l/s): 250
- Pressure (hPa): 3
- Electrical power (W): 450
- Speed regulation: Single speed
- Voltage (V): 115/200

- Type: AC Axial
- Max. speed (rpm): 7800

The brake fan reduces brake cooling time by blowing ambient air over the brake and wheel assembly using an electric fan mounted on the wheel. Please note that the maximum recommended take-off temperature indicated on the instrument panel may have different values depending on whether or not a brake fan is used[20].

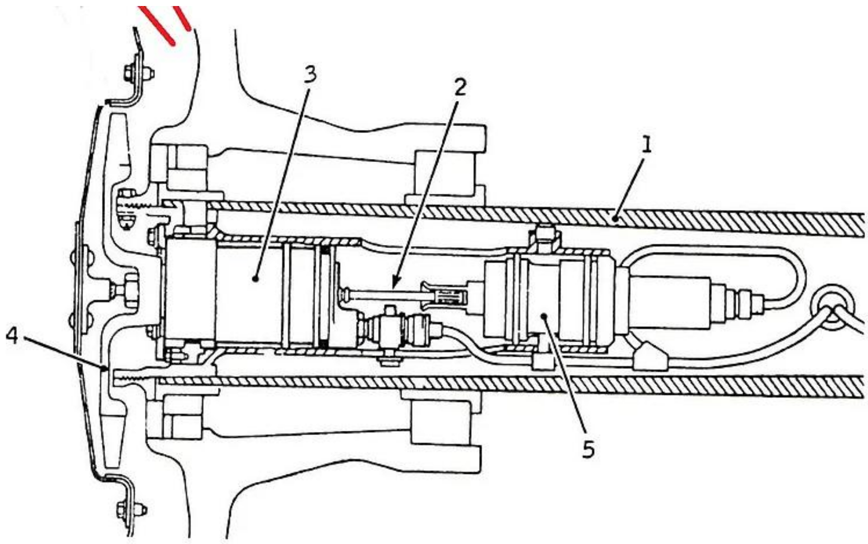

Figure 2.5 Cross-sectional view of a fan

1. Axle; 2. Generator drive shaft; 3. Motor; 4. Fan; 5. Tachometer generator

2.5. Conclusion for special part

The following conclusions can be drawn from this process of analysis of the landing gear

- Firstly, the background to the invention and development of the oleo strut is presented
- The next section describes the application of the oleo strut in aircraft and the role it plays
- Presentation of the oleo struts principle of operation and the aircraft hydro-pneumatic system with which it is used
- Review the design considerations for oleo struts
- The selected oleo struts were tested for strength, using isothermal, polytropic and combined algorithms.

- Introduction to the aircraft landing gear cooling system and important parameters

Mechanical, hydraulic and non-mechanical dampers were chosen as the most favourable dampers for this analytic study. After expressing the fluid relations in this system, the gas relations in the isothermal and polytropic modes were studied. Taking into account the allowable shear stress intensity in the cylinder, it is determined that if the multi-mode pressure is exceeded, this is the mode combination chosen as the best mode to reduce the forces and vibrations entering the system.

General conclusion

During this analytical aircraft design were defined next achievements:

- preliminary designing of the long-range passenger airplane with maximum passengers of 240;
- cabin layout of the long-range passenger aircraft with maximum passengers of 240;
- Calculating the position of the centre of gravity in five different situations in the range of 25.43-25.81;
- Features a GE CF6 high bypass turbofan engine located on the wing, providing high cruising speed and a good power to weight ratio;
- Reviewed the concept and key principles of passenger airplane development;
- Background on the historical development of landing gear shock absorber, installation and operation procedures as well as the damping principle according to my aircraft
-Introduction to the structural features and relevant strength standards and precautions regarding shock absorber
- Testing of selected shock absorber at the landing situation and related calculations, including isothermal, polytropic and combined calculations
- A brief description of the landing gear cooling system, its importance to the landing gear during landing and the relevant parameters

The aerodynamic characteristics of the aircraft designed here are excellent and the relevant improvements have been made to improve passenger comfort.

The design aircraft is based on the chosen prototype with some geometrical parameters refined to meet the requirements of modern passenger aircraft. In the future, this airliner will be competitive on the market. This aircraft meets all the requirements of EASA guidelines and CS-25.[17]

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Appendix A

INITIAL DATA AND SELECTED PARAMETERS

Passenger Number Flight	240
Crew Number	2
Flight Attendant or Load Master Number	8
Mass of Operational Items	3601.5kg
Payload Mass	26400kg
Cruising Speed	870km/h
Cruising Mach Number	0.8162
Design Altitude	12.5km
Flight Range with Maximum Payload	18000km
Runway Length for the Base Aerodrome	3.3km
Engine Number	2
Thrust-to-weight Ratio in N/kg	2.6
Pressure Ratio	34.80
Fuel-to-weight Ratio	5
Aspect Ratio	5
Taper Ratio	0.4510
Mean Thickness Ratio	0.110
Wing Sweepback at Quarter Chord	31degree
High-lift Device Coefficient	0.93
Relative Area of Wing Extensions	0

Wing Airfoil Type - supercritical
Winglets - yes
Spoilers - yes

Fuselage Diameter	5.60 m
Fitness Ratio	9
Horizontal Tail Sweep Angle	17.0degree
Vertical Tail Sweep Angle	45.0degree

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point	0.549
Induce Drag Coefficient	0.0894

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

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	0.000948
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	0.168
Start Thrust-to-weight Ratio for Safe Takeoff	0.870
Design Thrust-to-weight Ratio	3.013
Ratio $D_r = R_{cruise} / R_{takeoff}$	0.790

SPECIFIC FUEL CONSUMPTIONS (in kg/kN*h):	
Takeoff	35.9228
Cruising Flight	57.6607
Mean cruising for Given Range	62.2440

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
Fuselage	0.07769
Equipment and Flight Control	0.09947
Additional Equipment	0.00695
Operational Items	0.01812
Fuel	0.39618
Payload	0.13283

Airplane Takeoff Weight	198748 kg
Takeoff Thrust Required of the Engine	2249.44 kN

Air Conditioning and Anti-icing Equipment Weight Fraction 0.0174
Passenger Equipment Weight Fraction 0.0097
(or Cargo Cabin Equipment)
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction 0.0057
Furnishing Equipment Weight Fraction 0.0101
Flight Control Weight Fraction 0.0040
Hydraulic System Weight Fraction 0.0122
Electrical Equipment Weight Fraction 0.0269
Radar Weight Fraction 0.0024
Navigation Equipment Weight Fraction 0.0036
Radio Communication Equipment Weight Fraction 0.0018
Instrument Equipment Weight Fraction 0.0042
Fuel System Weight Fraction 0.0126

Additional Equipment:
Equipment for Container Loading 0.0048
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 299.8 km/h
Acceleration during Takeoff Run 2.39 m/s^2
Airplane Takeoff Run Distance 1445 m
Airborne Takeoff Distance 578 m
Takeoff Distance 2024 m

CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed 284.81 km/h
Mean Acceleration for Continued Takeoff on Wet Runway 0.36 m/s^2
Takeoff Run Distance for Continued Takeoff on Wet Runway 22229 m
Continued Takeoff Distance 2807.68m
Runway Length Required for Rejected Takeoff 2908.73m

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight 135644 kg
Time for Descent from Flight Level till Aerodrome
Traffic Circuit Flight 23.6 min.
Descent Distance 57.06 km
Approach Speed 255.06 km/h
Mean Vertical Speed 2.05 m/s
Airborne Landing Distance 519 m
Landing Speed 240.06 km/h
Landing run distance 795 m
Landing Distance 1314 m
Runway Length Required for Regular Aerodrome 2195 m

Runway Length Required for Alternate Aerodrome 1866 m

ECONOMICAL EFFICIENCY

These parameters are not used in the project