МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ

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Кафедра конструкції літальних апаратів

ДОПУСТИТИ ДО ЗАХИСТУ
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ДИПЛОМНА РОБОТА
(ПОЯСНЮВАЛЬНА ЗАПИСКА)
ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ
"БАКАЛАВР"

Тема: «Аванпроект пасажирьского середньомагістрального літака пасажиромісткістю до 160 осіб»

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Київ 2020

MINISRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

Department of Aircraft Design

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

DIPLOMA WORK
(EXPLANATORY NOTE)
OF EDUCATIONAL DEGREE
«BACHELOR»

Theme: «Preliminary design of a medium range aircraft with a capacity of up to 160 passengers»

Performed by: __________ Fatemeh Askari

Supervisor: PhD, Senior Lecturer __________ V.I. Zakiev

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

Kyiv 2020

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty

Aircraft Design Department

Academic degree «Bachelor»

Specialty: 134 "Aviation and Rocket-Space Engineering"

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

TASK

for bachelor diploma work

FATEMEH ASKARI

1. Theme: «**Preliminary design of a medium-haul aircraft with a capacity of up to 160 passengers** »

Confirmed by Rector’s order from 05.06.2020 year № 801/CT

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

3. Work initial data: cruise speed V_{cr}= 840 km/h, flight range L = 6000 km, designed altitude H = 10,5km.

4. Explanatory note argument (list of topics to be developed): introduction; part 1: the analytical part, choice and substantiations of the airplane scheme, choice of initial data, engine selection, aircraft layout and center of gravity position; part 2: conversion of passenger aircraft to cargo aircraft.

5. List of the graphical materials: general view of the passenger airplane (A1×1); layout of the passenger airplane (A1×1); layout of the cargo airplane (A1×1); half

wing of airplane (A4×1) PREFORMED IN AutoCAD.

6. Calendar Plan

Task	Execution period	Signature
Task receiving, processing of statistical data.	24.05.2020–27.05.2020	
Aircraft take-off mass determination.	29.05.2020–30.05.2020	
Aircraft centering determination	01.06.2020–04.06.2020	
Graphical design of the aircraft and its layout.	04.06.2020–12.06.2020	
Preliminary examination and defense of the diploma work	14.06.2020–21.06.2020	

7. Task issuance date: 24.05.2020

Supervisor of diploma work ___________ V.I. Zakiev

Task for execution is given for ___________ Fatemeh Askari

ABSTRACT

Explanatory note to the diploma work « Preliminary design of a medium range aircraft with a capacity of up to 160 passengers» contains:

sheets, figures, tables, references and drawings.

Object of the design is development of the mid-range aircraft with capacity of up to 160 passengers.

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

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

The diploma work contains drawings of design of the mid-range aircraft, passenger capacity up to 160 people, calculations and drawings of two categories of the aircrafts layouts and the ULD accommodated inside the cargo airplane.

The results of the diploma work can be implemented to the academic education and also it can be used for the design bureaus.

CONTENT

INTRODUCTION

Nowadays, we can observe the dramatic growth of passenger traffic in aviation, in local airlines in particular, due to high demand and facile transportation. Respectively, there is need for short to mid-range to ensure profitable operation of aircrafts with most reliability and regularity of flights in the highly competitive global market.

Therefore, there are some requirements of the international organization of air transport in civil aviation that each aircraft must meet, for example:

- Flight safety;
- Increasing comfort operation;
- Reducing emissions of harmful gases, and others;
- The plane projected must also satisfy the following requirements;
- Comfortable passenger compartment that meets the highest requirements;
- Operation in a wide range of temperature in different climates and seasons;
- Reliability and ease of operation and travel.

This diploma project considers design of an aircraft with up to 160 passengers, providing facilities required for comfort of riders during a short to medium range flight.

The ideas and calculations which are essential to design an airplane are presented in the first part of this project. For example, geometric characteristics and shapes fuselage, wing and tail unit and location of engines or landing gears for exterior design and passenger cabin layout, specifying location of galley and lavatories as interior design.

To elaborate a better view of each mentioned parameter, quantitative data and relative calculations are provided as well.

The second part of work which is based on the idea of aircraft conversion contains explanation of this procedure and several information and steps of calculations to point to some imperative limitations for a cargo version of the designed prototype, in particular.

Hence, a unit load device (LD3-45) which is commonly used in aviation cargo transport is introduced.

Then, conditions of loading the plane with such ULD and maximum payload of the aircraft are calculated, too.

Drawings of the designed prototype and some parts in particular are provided beside calculation and magnitude to support the visual realization of the project.

At the end of each part, in the conclusion section, results of each part can be found, briefly.

I compromise both planes and offer several recommendations in the final part of the research.

PART 1

PRELIMINARY DESIGN OF NARROW-BODY AIRCRAFT WITH UP TO 160 CAPACITY

This part shows the steps of preliminary design of a prototype with 160 passengers.

We are going to consider coordination of components and elements used in the assembly of an aircraft to provide safety and efficiency for 2-3 hours of flight.

The process starts with selection of data and geometry and body shape of the plane and engine installation considering aerodynamic efficiency and fuel consumption.

Fuselage layout design comes next. In this stage, passengers' life security and comfort play important roles. For instance, to place required equipment and compartments in the most suitable position, while providing a spacious passenger cabin.

Eventually, calculation of the first part ends with center of gravity calculation and etc.presented in several tables.

1.1Analysis of prototypes and short description of designing aircraft

Choice of the project data

The selection of parameters for optimum design of the aircraft is a multidimensional optimization task, aimed at forming a "look" promising aircraft. In its configuration referred to the whole complex flight-technical, weight, geometrical, aerodynamic and economic characteristics.

In formation of the "Appearance of the plane" in the first stage, statistics methods transfers, approximate aerodynamic and statistical dependence are widely used. The second stage uses a full aerodynamic calculation; aircraft specified formulas of aggregates weight calculations, experimental data.

Prototypes of the aircraft, taking for the designing aircraft were Airbus 320 in one class 150-180 passengers.

“The A320 Family is the most successful aircraft family ever and it was born ambitious. As the first civil aircraft to pioneer fly-by-wire technology, it has set the standard ever since its arrival and, thanks to significant annual investment of 300 million euros; the A320 Family continues to innovate.

The A320 Family comes with a unique CLS option: it is the only single-aisle aircraft that is able to load pallets and containers on the lower deck. Together with its outward-opening cargo doors and large cargo compartment cross-section, this maximises the usable cargo volume.

The A320neos boast the very latest engines, large wingtip devices (Sharklets) and an innovative cabin – continuing to go from strength-to-strength as the most comfortable, fuel-efficient and environmentally-friendly single-aisle aircraft.”[8] This is how Airbus Company introduces its most popular prototypes in the current aviation market.

As far as they are reference existing prototypes of this diploma project, some parameters of A320 family (mainly varieties of A320 aircraft) that were considered in software method of calculation are shown in the tables.

Table.1.1. Geometrical specification of A320 family

Type	A318	A319	A320	A321
Range of flight; km	5,750	6,950	6,100	5,950
Number of seats	107	124	150	185
Length; m	31.44	33.84	37.57	44.51
Wingspan, m	34.10			
Wing Area, m^2	122.6			
Wing Sweep Back	25 Degrees			
Tail Height, m	12.51	11.76	11.76	11.76
Fuselage Width, m (Exterior)	3.95			
Cabin Width, m	3.70			
Fuselage Height, m	4.14			

Table.1.2. Operational specification of A320 family

Type	A318	A319	A320	A321
Freight Capacity, m^3	21.21	27.62	37.41	51.73
Cruising Speed	Mach 0.78 (828KPH / 511 MPH at 11,000 Metres / 36,000 ft)			
Maximum Operating Speed	Mach 0.82 (871KPH / 537 MPH at 11,000 Metres / 36,000ft)			
Operating Empty Weight, kg (OEW)	39,500	40,800	42,600	48,500 kg
Maximum Zero Fuel, kg Weight(MZFW)	54,500	58,500	62,500	73,800
Maximum Landing Weight(MLW), kg	57,500	62,500	66,000	77,800
Maximum Take-off Weight(MTOW), kg	68,000	75,500	78,000	93,500
Takeoff Distance, m (Sea Level ISA)MTOW	1,828	2,164	2,090	2,560
Landing Distance, m	1,400			1,500

(Sea Level ISA)MLW				
Engines	CFM International CFM56-5 series	CFM International CFM56-5 series		
Engines	Pratt & Whitney PW6000 series	IAE V2500 series		
Thrust x 2, kN	96 to 106	98 to 120	111 to 120	133 to 147

The relative coordination of different parts of the aircraft was estimated according to the prototypes, optimum conditions and objective path of motion. The geometric parameters of prototypes were implemented. Aerodynamic layout of the aircraft will affect its operational characteristics and aerodynamic. The proposed scheme of the plane has profitable, high safety and comfort bases.

1.2 Brief description of the main parts of the aircraft

The plane is a cantilever low-wing monoplane with bypass turbofan engines placed in rear part of fuselage and tricycle landing gear with a front single-strut landing gear and two main gears.

- A swept wing with a high aspect ratio, which is based on new supercritical profile;
- Fuselage has circular cross section.

The aircraft has a fuselage mounted tail unit construction, with adjustable vertical stabilizer mounted on the fin. Rudder and elevators are equipped with aerodynamic balance.

Fuselage design description

The fuselage is all-metal, beam-stringer construction (like semi-monocoque). This type of construction is characterized by the presence of a relatively thick skin, supported by stringers and frames to increase the strength of the fuselage and fail-safe of the structure.

The fuselage has a rational combination of benefit of its shape and elongation of connected elements with low resistance and a high critical Mach number.

In the cockpit, there are seats for the first and second pilots. There is also a space for a flight engineer crew member, as well.

The first pilot's seat is located on the left while the second pilot's seat is on the right. The instrument panels are installed in front of them and an average pilot console is between them.

There are two flight attendance seats, a small galley and a lavatory close to the front exit doors. The main galley, two lavatories and two more flight attendance seats are in rear part of passenger cabin. 160 economy class passenger seats are arranged in 3-3 rows of seats and a row of 2-2 seats close to middle exit doors. The designed layout of passenger cabin has three symmetrical pairs of exit door in front, middle and aft part.

Windows are on side walls of aisle, there are emergency exits on the left and right side. At the bottom on the shelves are installed service panels with individual ventilation nozzles, lights, buttons for switching on individual lighting, the call button of the flight attendant and the light numbering of the seats. Plafonds of general interior lighting are located in the central part of the ceiling; in addition, there are lights for the sides and the lower part of the overhead bin compartments. [4]

The main force elements of the fuselage are frames, stringers, longitudinal beams of the chassis front support awning.

The crew cabin is located in the nose part of the fuselage.

- This allows pilots to easily control the plane in situation.
- Provides sufficient visibility through its conical windshields for pilots.
- Accessibility to panels and navigation systems on board and takeoff and landing switches for pilots to accomplish their responsibility with the help of equipment located there.
- Accessibility to power supply, APU and engine, air conditioning system, fire extinguishing system, hydraulic system and electric system is another advantage of accommodating flight crew and control panel in the same coordination.

The major function a passenger cabin is comfort and safety of travelers.

Seats installed in the aircraft for crew and passengers have to meet requirements. The cabin interior must include facilities such as appropriate lighting, lavatories and galley according to number of passengers. There are more equipment such as monitors and game instruments for entertainment during flight.

Oxygen masks, fire extinguishers, medical tools, EXIT sign next to each door and light marking are other properties of a passenger plane.

Wing design description

An arrow-shaped wing of the caisson structure

It consists of a Centro plane and two detachable parts of the wing, which are attached along the ribs. The main legs of the chassis and the gondolas in which they are retracted in flight, also ailerons and aerodynamic partitions are installed on the wing.

The nose part of the wing is equipped with an air-thermal and an electro thermal anti-icing device. The warm air in the sock of the center wing is fed from the aircraft engine compressors to be used if necessary.

The wing consists of longitudinal and transverse set of elements and skin.

The wing has a relatively small distance from the ground, which increases the lift factor C_Y due to the influence of the ground, thereby it leads to advance takeoff and landing features.

Aircraft is equipped with a huge landing gear to reduce ground load. This enables the aircraft to operate from the same runways. The aircraft has two two-wheel main landing gears, fitted with large low-pressure tires that retract into pods extending from the trailing edges of both wings; and a two-wheel nose gear unit. Oleo-pneumatic shock absorber used in the landing gear provides a much smoother ride on bumpy airfields compared to other planes.

The horizontal plumage relative to the wing is exceeded, which has a positive effect on longitudinal stability and controllability of the plane.

There is less danger uncertainty to the aircraft and passengers while landing with a retracted landing gear; during landing with the landing gear retracted on the ground, the wing perceives the impact energy and protects the passenger cabin; While boarding on the water, it is immersed in water along the wing, which gives the fuselage additional buoyancy.

The wing is made swept, which creates a greater M_{cr} and a weaker wave crisis; however there are several drawbacks related to sweep wing structure:

- Large tearing speeds and landing and a long run and run length consequently.
- It has smaller aerodynamic qualities than direct, greater drag of the aircraft and a shorter range and the duration of the flight.
- Have a tendency to end the flow from the wing.
- Lowest coefficient of maximum lift.
- External lateral stability, leading to aircraft swinging.
- The lateral controllability is reduced at large angles of attack due to a stall from the wing ends, has a reverse roll response.

The lateral stability decreases with M> Mmax (Mach number)

Tail unit design description

The empennage is swept and fuselage mounted. It consists of vertical and horizontal tail units.

Vertical tail unit includes fin and rudder;

Horizontal tail unit consists of stabilizer and elevator;

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

The vertical and horizontal plumage profile is symmetrical. Symmetric profile allows maintaining the same character of aerodynamic loads during deflection of rudders in different directions; in addition, it has a smaller resistance.

Vertical tail unit has a rather high relative thickness of the profile in comparison with horizontal tail unit, to reduce the mass of fin loaded with forces, both from vertical and horizontal tail unit.

Landing gear design description

The chassis is a support system that provides the required position of the aircraft during parking and its movement during takeoff, landing and taxiing on the aerodrome.

On this plane, the chassis is made according to a three-bearing scheme and is retracted back by flight. Such a scheme approves to obtain a stable airplane movement through the airfield, effective maneuverability, thanks to the use of the control of the turning of the wheels of the front leg, the horizontal position during stationary position and motion. The chassis with the nose wheel allows the plane to take off and land in a strong lateral wind, as well as rectilinear movement during the run and takeoff of the aircraft.

Front or nasal support (strut) is placed in front of the center of gravity to avoid overturning "on the nose" and apply effective braking of the wheels to reduce the run.

The main supports (struts) are located behind the center of gravity of the aircraft. They are tilted back in the released position; variation of it depends on the amount of compression of the shock absorbers.

The front support has two wheels, and each main one has a bogie with six paired wheels.

Pneumatics of wheels perceives the load during landing and moving on aerodrome and passes it to the supports.

Retracting the chassis back has its advantages and disadvantages. Such retracting does not cause a significant displacement of the center of gravity of the aircraft and does not require increased capacity of the lift cylinders, since in this case it is not necessary to overcome airflow resistance.

The aircraft has a control system for steering the wheels of the front support, which greatly improves the maneuverability of the aircraft when taxiing. The steering of the wheels is controlled by deflecting the rudder pedals.

The main legs of the chassis have a hydraulic braking system for the wheels and devices that automatically adjust the braking force of the wheels.

Power plant

CFM56-5 is commonly used in such prototypes. These series of engines are manufactured by CFM International and have been operating since 1974.

Of their features high bypass ratio with thrust range from 82 TO 150 KN.

Control system

The primary and secondary flight control surfaces on the wing and tail unit (ailerons, flaps, slats, spoilers, elevator, rudder etc…) and the steering wheels are employed to ensure the controllability and stability of the airplane.

Each pilot has a double control lever of the system, and it is possible for both pilots to run the control system at the same time.

When either pilot are controlling the aircraft by operating with control levers, pedals or steering wheels it is called steering mode.

1.3 Aircraft layout and geometric calculation

Layout of the aircraft consists of constructing the relative positioning of its components and constructions, and all of the loads and payloads (passengers, luggage, cargo, fuel, etc).

The selection of the composition plan and the parameters of the aircraft are guided by the best compliance with the operational requirements to aviation design.

1.3.1 Wing geometry calculation

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

Full wing area with extensions is: S_w=140 m,

Relative wing extensions area is 0.0

Wing span is: l_w=36.47m

Root chord is: b_0=5.6 m

Tip chord is: b_t=2.07m

Calculated mean aerodynamic chord; b_{mac}=4.105 m

I use the geometrical method of mean aerodynamic chord determination Mean aerodynamic chord. The drawing of which is displayed.

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_{ai}=6.84m

Aileron area: S_{ail}=4.55 m^2

Due to this the span and the area of high-lift devices may be increased, which improves take-off and landing characteristics of the aircraft.

Aerodynamic compensation of the aileron:

Axial $S_{axinail} \leq (0.25 \ldots 0.28)\ S_{ail} = 1.1375\ m^2$

Inner axial compensation $S_{inaxinail} = (0.3...0.31)\ S_{ail} = 1.365\ m^2$

Range of aileron deflection

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

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

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

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 Flayers flaps;

b_s = 0.1..0.15 – slats.

Effectiveness of high-lift devices (C^*_{ymaxl}) rises proportionally to the wing span increment caused by high-lift devices. For this purpose, we are supposed to obtain the largest span of high lift devices ($l_{hld} = l_w - D_f - 2l_{ail} - l_n$ (1.1)) which appears due toextension of flight spoiler and maximizing the engine and landing gear nacelles.

l_{hld} – largest span of high lift

l_w – wing span

D_f – diameter of fuselage

l_{ail} – span of aileron

l_n – length of airplane nose

All in meter;

We must use the statistics and experience of manufacturing domestic and foreign aircraft in order to choose designs with structurally powered structures, hinged and kinematic designs of lifting devices. It should be noted that in most existing structures, the elements of electrical devices are done by longeron structural strength designs.

1.3.2 Fuselage layout and geometric calculation

To choose the configuration and size of fuselage cross-section we are supposed to consider the aerodynamic demands.

To be applicable to the subsonic passenger and cargo aircrafts ($V < 800$ km/h) , in the way that wave resistance doesn’t affect it. So we need to choose from the conditions of the list values friction resistance C_{xf} and profile resistance C_{xp}. During the transonic and subsonic flights, shape of fuselage nose part affects the value of wave resistance C_{xw}. Therefore, circular shape of fuselage nose part is applied to minimize its wave resistance.

Consequently transonic airplane may have $l_{nfp}=5.365$ m.

Where l_{nfp} is length of fuselage nose part;

Except aerodynamic requirements consideration during the selection of cross-section shape, we must consider the strength and layout requirements as well.

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}.

The length of the fuselage is guaranteed according to the aircraft layout, position of the aircraft's center of gravity, scheme and the conditions of the landing angle of the attack.

$l_f=37.56$m -Fuselage length

$\lambda_{np}=1.358$ -Fuselage nose part aspect ratio

$l_{TU}= 12.264$m -Length of the fuselage tail unit

For middle section of passenger and cargo airplanes fuselage, size of passenger or cargo cabin is the priority. One of the main parameters, to determine the middle section of passenger airplane fuselage is the height of the passenger cabin.

For such single aisle, mid-range prototypes we choose:

H_C=1.85 m – hight of passenger cabin

b_{asl}=0.5m – width of aisle

h'=1m – window to floor distance

Circular cross-section is efficient from design point of view, because it will be the strong and the light. But for passenger and cargo placing this shape is not always the most convenient one. In the most cases, one of the most suitable ways is to use the combination of two circles intersection [5], or oval shape of the fuselage. It is worthy of remembering that the oval shape is not suitable in the manufacturing, because the upper and lower panels will bend due to extra pressure and will demand extra bilge beams, and other construction amplifications.

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

For economic aisle with the scheme of seats in the one row (3 + 3) determine the appropriate additional dimensions as:

B_c=3460 mm (3.46 m) – width of passenger cabin

L_c=21500 mm (21.5 m) – length of passenger cabin which is for one class without any class divider in this particular case.

Luggage and cargo compartment

As a matter of fact, the unit of load on floor for such prototypes is:

$K = 400\ldots 600$ kg/m^2

Correspondingly, S_{crg}=20 kg/m^{2,} which is area of cargo compartment and

V_{crg}=32 m^3 (cargo compartment volume).

Galleys and buffets

If flight duration is less than 3 hours, food seving is not necessary. In this case, cupboards are provided for water and tea instead.

Kitchen cupboards must be placed close to the exit doors between the cockpit and passenger or cargo cabin separated by doors. T protect the freshness of meals, they should be kept far from lavatories or wardrobe.

V_{gal}=16 m^3 - volume of buffets (galleys)

S_{gal}=8.64 m^2 - area of buffets (galleys)

W_m=0.8 kg -weight of meals including beverages per passenger (breakfast, lunch or dinner)

Food is served every 3.5…4 hours flight.

Design of galley is similar to prototype.

Lavatories

Number of toilet facilities is determined according to the number of passengers and flight duration:

One toilet per 40 passengers if t =2 to 4 h and 50 passengers $t<2$ h to 60 passengers.

t is flight duration [hour]

The parameters of lavatories are chosen according to the existing prototype.

n_{lav}=3 – number of lavatories

S_{lav}=1.5 m^3 - area of lavatory

b_{lav}=1 m - width of lavatory:

Design of lavatory is similar to the prototype.

1.3.3 Tail unit geometric calculation

One of the most important tasks of the aerodynamic layout is selection of tail unit disposition. To ensure the longitudinal stability during overloading, its center of gravity should be placed in front of the aircraft focus and the distance between these points, related to the mean wing aerodynamic chord (MAC), to issue the longitudinal satability.

Determination of the tail unit geometrical parameters:

S_{VTU}=24.5 m^2 -area of vertical tail unit

S_{HTU}=32.183m^2 -area o horizontal tail unit

Values L_{HTU} and L_{VTU} (length of horizontal and vertical tail units repectively) depend on some factors:

- The length of the nose part and tail part of the fuselage
- Sweptback and wing location
- The conditions of stability and control of the airplane.

b_{0HTU}=3.284m -root chord of horizontal stabilizer

b_{tHTU}=1.312m -tip chord of horizontal stabilizer

b_{0VTU}=5.248m -root chord of vertical stabilizer

b_{tVTU}=1.968m -tip chord of vertical stabilizer

1.3.4 Landing gear characteristic and geometric calculation

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

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

B=11.27m – wheelbase of landig gear (nose to main landing gears distance)

B_m=0.821m – main landing gear to center of gravity distance

B_n=10.45m – nose landing gear to center of gravirty distance

T=7.59m – wheel track (distance between two main landing gears)

Ycg=0.316m – height of center of gravity

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

The load on the wheel is determined:

K_g = 1.8 – dynamic coefficient

F_n=6880.81N – nose wheel load

F_m=87556.43N – main wheel load

Table.1.3. Aviation tires for designing aircraft

Main gear		Nose gear	
Tire size	Ply rating	Tire size	Ply rating
49x18	30	30x8.8mm	16

1.4 Power plant selection

Table.1.4. the power plant selected for the prototype

Model	Thrust	Bypass ratio	Dry weight
CFM56-5B4	120 KN	5.7	2380 kg

The engines efficiency is ultimately dominant in aviation. They have to supply adequate power to support all functional systems during flight and create necessary thrust to keep the plane the safe altitude and aerodynamic stability as well.

Table.1.5. CFM56-5B4 specification

Versions	CFM56-5B4
Applications	A320
Max. takeoff thrust (kN)	120
Temp. at flat rating (F°)	111
Bypass ratio	5.70
Max climb thrust (kN)	25.37
Length (m)	2.6

Fan diameter (m)	1.735
Number of fan/low-pressure/high-pressure compressor stages	1+4+9
Number of low-pressure/high-pressure turbine stages	1+4
Dry weight (kg)	2381.4

Fuel consumption is another important issue related to engine type mounted on the airplane. Therefore, selection of the power plant with respect to configuration and properties of the aircraft should be carefully contemplated.

1.5 Center of gravity calculation

1.5.1calculation of the equipped wing center of gravity

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 mounted under the wing, included the names given in the table 1.6.The example list of the mass objects for the aircraft, where the engines are located in the wing, included the names given in the table 1.6. The mass of AC is 94454 kg. Coordinates of the center of power for the equipped wing are defined by the formulas:

$$X_w^{/} = \frac{\Sigma m_i^{/} x_i^{/}}{\Sigma m_i^{/}} \qquad (1.2)$$

Table.1.6. Equipped wing masses

object name	Mass		CG coordination,Xм	94454
	units	Total mass m(i)		Mass moment
Wing(structure)	0.125	11846.42	1.85	21887.4
fuel system	0.009	850.08	1.85	1570.62
airplane control, 30%	0.00465	439.21	2.46	1081.98
Electrical equipment, 30%	0.00317	299.42	0.410577	122.93
anti-ice system , 70%	0.01449	1368.64	0.41	561.93
Hydraulic systems , 70%	0.01085	1024.82	2.46	2524.62
power plant	0.0905	8548.09	2.46	21057.88
equipped wing without landing gear and fuel	0.25808	24376.68	2.0	48807.37
Nose landing gear	0.007748	731.829	-11.5	8416.0403
Main landing gear	0.030992	2927.32	2.052	6009.44

Fuel	0.30467	28777.30	1.845965	53121.888
total	0.60149	56813.1364	2.048025	116354.752

1.5.2 Calculation of the equipped fuselage center of gravity

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 3.2.

The CG coordinates of the FEF are determined by formulas:

$$X_f = \frac{\Sigma m_i^{/} X_i^{/}}{\Sigma m_i^{/}}; \tag{1.3}$$

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

$$m_f x_f + m_w (x_{MAC} + x_w^{/}) = m_0 (x_{MAC} + C) \tag{1.4}$$

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

$$X_{MAC} = \frac{m_f x_f + m_w \cdot x_w^{/} - m_0 C}{m_0 - m_w} \tag{1.5}$$

where m_0 – aircraft takeoff mass, kg;

m_f – mass of fully equipped fuselage, kg;

m_w – mass of fully equipped wing, kg;

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°...40° C = (0,28...0,32) B_{MAC}

at X= 45° C = (0,32...0,36) B_{MAC}

Table1.7.Trim sheet of equipped fuselage masses

objects names	Mass		C.Gcoordinates Xi, м	
	units	total mass		Mass moment
Fuselage	0.08646	8166.49	18.78	153366.73
horizontal tail	0.00961	907.70294	34.35	31179.596
vertical tail	0.00877	828.36	34.35	28454.22
Radar	0.003	283.36	0.5	141.68
radio equipment	0.0023	217.24	1	217.24
instrument panel	0.0053	500.60	2.5	1251.51
Aero navigation equipment	0.0045	425.04	2	850.08
lavatory1, galley 1	0.0111	1048.43	4.75	4980.08
lavatory2,3, galley 2	0.0111	1048.4394	31	32501.62
Aircraft control system 70%	0.00385	363.64	18.78	6829.30
hydro-pneumatic sys 30%	0.00465	363.64	26.29	9561.03
electrical equipment 90%	0.02853	2694.77	18.78	50607.83
seats of flight attendence aft	0.00014822	14	29.7	415.8
furnishing and thermal equipment	0.0111	1048.43	18	18871.9
anti ice and airconditioning system	0.0207	1955.19	30.05	58749.78

passenger seats (economic class)	0.0135	1280	20	25600
seats of flight attendence front	0.00014822	14	9	126
seats of pilot	0.0003176	30	2.5	75
equipped fusel without payload	0.225	21189.4	18.58	423779.45
flight attendance front	0.0014822	140	9	1260
on board meal	0.00169395	160	31	4960
Baggage	0.05081839	4800	18.78	90144
flight attendance aft	0.0014822	139.99	29.7	4157.99
Crew	0.0014822	140	2.5	350
Passengers(economy)	0.11857624	11200	20	224000
TOTAL	0.4006708	37769.4	19.82	748651.44
TOTAL fraction	1.0021608			

1.5.3 Calculation of center of gravity positioning variants

The list of mass objects for center of gravity variant calculation given in Table 1.8 and Center of gravity calculation options given in table 1.9, applying data of two previous tables.

Table.1.8. Calculation of center of gravity positioning variants

Name	mass in Kg	coordinate	mass moment
object	m_i	$X_{i,}$, м	Kg.m
equipped wing (without fuel and landing gear)	24376.68	24.55	598687.8
Nose landing gear (extended)	731.82	5.1	3732.33
main landing gear (extended)	2927.31	22.51	65899.28
fuel	28617.3	19.73	564839.7
equipped fuselage (without payload)	21189.40	18.58	393699
payload	16439.99	19.74	324522
crew	140	2.5	350
nose landing gear (retracted)	731.83	4.077	2983.67
main landing gear (retracted)	2927.32	22.51	65899.28
reserve fuel	3321.002	20	66420.05

Table.1.9. position variants of aircraft center of gravity

Name of position	Mass, m_i kg	mass moment m_iX_i	center of mass	center X_C %
take off mass (L.G. extended)	94454	1951730.076	20.66	28
take off mass (L.G. retracted)	94454	1950981.41	20.65	27
landing weight (LG	69126.23	1453310.44	21.024	36

extended)				
ferry version	77982.53	1623646.53	20.82	31
parking version	49225.23	1062018.40	21.57	50

Conclusions to part 1

Characteristics of different parts of prototypes such as wing, fuselage and landing gear were studied and described.

Their capacity is 100- 185 passengers.

The cabin has necessary provision for a secured mid-range flight for passengers and easy operating for pilots due to logical positioning of panels and tools.

The elements applied in the structure of the prototype provide excellent controllability, stability, strength and aerodynamic efficiency of flight operation simultaneously.

The CFM56 engine which is typical for A320 family was introduced in the respective analytical part.

In another word:

- preliminary design of the middle range aircraft with capacity of up to 160 passengers;
- the cabin layout of the mentioned middle range aircraft;
- the calculations of center of gravity of the airplane;
- the calculation of the main geometrical parameters of the landing gear;
- the extract of the wheels, which satisfy the requirements;
- the design of nose landing gear;

Considering optimal passenger comfort provides:

- rational layout and convenient service facilities adapted;
- enough room for passengers and service on board;

- modernized interior design of the cabin by application of advanced technology;
- Minimum noise produced by aircraft and engine;

Installation of turbofan engines CFM56-5B4 type provides high cruise speed and good thrust-to weight ratio for such prototypes taking to account max capacity of designed prototype.

PART 2

CONVERSION OF PASSENGER AIRCRAFT TO A FREIGHTER

The plan of the second part is to study transformation of the same prototype to a cargo one with two decks to carry cargo, which starts with a brief explanation of the reasons of choice of such project.

There are varieties of aspects to fulfill such tasks. But I consider it from the unit load device (ULD) accommodation and loading point of view. LD3-45 is the reference to select dimensions for cargo holes doors, length and width.

Steps of calculation related to load limitation for the mentioned container is present in the work. It is essential for floor surface strength analysis taking to account applied forces. Similar to the passenger category, the center of gravity calculation is done for the freighter to estimate maximum allowable payload.

And finally, I conclude everything in couple of sentences to finish this part project, similar to the first one.

2.1Necessity of freighters in the abnormal situations

The current unpleasant situation which is occurred by the pandemic drew my attention to the procedure of conversion of one category of airplane to another.

Airliners are facing financial uncertainty from drop in revenue; while all fixed expenditures have remained for them. For example, they have to keep the plane airworthiness, staff salaries and airport and parking fees.

But due to high demand in goods and necessary equipment, the need in delivery of supplies around the world has sharply increased as well.

Hence freighters are in the center of attention, because of fast transportation and the capability to transfer plethora of loads from city to city, country to country and continent to continent in a short time i.e. couple of hours.

Considering mentioned reasons and others, of course, it seems to be an important issue for aviation industries to convert passenger aircrafts to cargo one. However this procedure is being used in several aviation factories in the world over the past decades to help Airlines repair and reuse old airplanes by changing the category of utilization, which definitely allows them to save and earn money as well.

Transformation of an Airbus A300 is good evidence; conversion of this prototype costs above 6 million euros, while manufacturing of it costs three times more.[10]

2.2 Actions that must be taken to convert a passenger aircraft to a freighter

The task is to transform a passenger plane to cargo.

To obtain general features of a cargo plane taking to account the requirements of aviation authorities, several actions must be taken.

Steps of transformation to be mentioned:

1. To rip everything that is superfluous to a freighter’s need (seats, galley and cables);

2. To fit the aircraft with cargo hatches; they are required to allow the stocks enter the plane. Therefore, their location on the fuselage, geometry and dimensions should be in the way that matches their function.

3. Reinforce the frame; a new frame must be applied to the aircraft for better strength and reinforcement. Therefore the plane is capable of transporting required mass of cargo. The aircraft may be jacked up into a neutral stress point for any modification of the airframe.

4. To plug windows; however they are necessary for a passenger aircraft, they are only causes of strength reduction in the structure of cargo one. This step supports aircraft safety and maintenance.

5. To discover defects on the visible and hidden areas; for instance, corrosion and fatigue cracks.

6. To replace old parts with the new ones.

7. To install a cabin floor with high strength; as far as, the primary function of a cargo plane is to carry tons of loads, it requires a significantly stronger floor compared to a passenger aircraft.

8. To install roller balls on the floor surface; they are designed to ease the motion of ULDs (pallets and containers) in the cabin.

Any other cargo compartment equipment which is necessary to facilitate the process of loading and unloading and to provide the attachment of ULDs to the cabin and their safety could be accessorized.

9. Fresh paint job; eventually the plane should look beautiful, although painting is a method to reduce the rate of corrosion appearance on the surfaces, too.

10. Eventually, the repaired aircraft must be checked for airworthiness approval according to aviation organization qualifications and requirements.

2.3 Cargo Cabin Layout

The cargo version of the prototype is a double-deck cargo plane.

The main-deck that used to be the passenger cabin; and the lower deck, which consists of forward and aft decks;

The bulk or lower part of fuselage is mostly used to carry passengers' baggage and some extra payload. Therefore I use dimensions similar to existing passenger prototypes for two lower-decks.

Regarded to length (37.56m) and diameter (3.95m) of fuselage my proposed dimensions for cargo holes are noted in the table2.1.

Table. 2.1. Dimensions of cargo holes

	Usable Length,m	Height, m	Width, m
Compartment1(main)	20	1.85	3.5
Compartment 2(forward)	5.4	1.5	3
Compartment3(aft)	6.5	1.5	3

2.4 Reference Unit Load Device

Unit load device is used in cargo planes to load large quantity of goods into the freighter. They ease the loading and unloading process in a short time. They also protect cargo in a better condition in the period of delivery specially ground operation, take-off, landing or any sudden unusual motion.

ULD is well attached to the body of fuselage using attachments, ropes for example, which supports the mentioned benefits of their use in cargo airplanes.

Each ULD has its own identification which helps users to choose the appropriate one for the specific purpose and apply proportionate equipment to operate, such as crane, pulleys and flooring system. Another important identification is dimension of the ULD that allows us to select the right on according to airplane geometry.

During my research, among two main types of unit load device i.e. containers and pallets, I found the container LD3-45 most recommended and applicable unit load device for such prototypes.

Below you may observe basic parameters of such unit load device.

Table.2.2. LD3-45 characteristics

External dimensions; L×W×H; m^3	2.44×1.53×1.14
Contact areQdimensions;m^2	1.53×1.63
Tare weight, kg	95
Maximum gross weight G, kg	1588
Internal volume,m^3	3.3
Door size, m^2	1.37×1.05

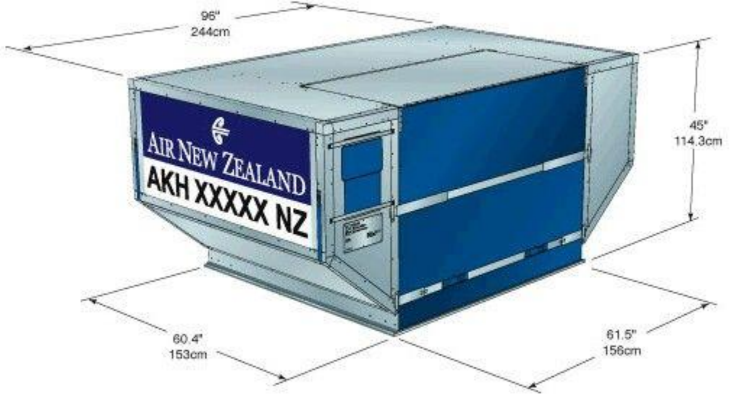

Fig. 2.1 ULD

The figure above (fig2.1) shows dimensions of LD3-45 in 3D.

In the further calculation, we will see how many of such containers can be place in each compartment at the same time.

2.5 Calculation of distribution allowance for a fully loaded unit load device

The stresses and forces that appear due to impact of ULD and floor surface can affect strength of the floor, i.e. the airplane structure. Weight and geometry of the object are the main factors to be considered in such analysis.

In the following section, three main loads that impact the floor from the containers placed on it are calculated for LD3-45 which may be compared to corresponding allowable loads for any designed floor. The reason of presenting such calculation is to elaborate the feature of the container for strength point of view.

Running load: Q_r=G/L (2.1) $\frac{15880}{2,44} = 6508.2\frac{N}{m}$

Area load: Q_a=G/A (2.2) $\frac{15880}{1.53\times1.63} = 6653.2\ N/m^2$

Contact load: Q_c=G/A' (2.3); which equals to area load in this case, without any load distribution device. G is maximum gross which includes the weight of the container and the loaded cargo.

2.6 Dimensions of cargo compartment and its doors

- There must be enough room for cargo and auxiliary equipment inside the plane.
- Doors must be designed in the way that ULD can enter the hole without any damage, crash or collision with fuselage structure.
- There should exist a small distance between side by side containers to avoid any collision between them and damage to cargo inside them.

According to possibilities that we have to apply several changes in the dimensions of cargo holes and door frames, I recommend them as shown in the table2.3.

It is worthy to note that four of passengers exit doors should be removed (aft and on the wing doors), while two front exits will remain for crew and perssonel use.

Table.2.3. Dimensions of cargo doors (expanded form of table.2.1)

	Usable Length,m	Height, m	Width, m	Door dimensions; widthxheight,m^2
Compartment1(main)	20	1.85	3.5	2.7×1.5
Compartment2(forward)	5.4	1.5	3	1.82×1.23
Compartment3(aft)	6.5	1.5	3	1.82×1.23

Suggested dimensions for main deck door allow us to load the container into the hole if its length (244cm) is parallel to longitudinal axis of the fuselage while its width (153cm) for lower-deck compartments.

2.7 Center of gravity calculation for cargo plane

The characteristics of freighter are similar to the designed passenger aircraft, except in some cases. For example, the pilot cabin is lengthier i.e. a greater coordination. Therefore, such differences are present in the center of gravity calculation to create a new design feature only. Hence, the explanation and description are same as for passenger aircraft (section 1.5).

The following tables display calculation of center of gravity for the cargo aircraft.

As the result of the calculus I received maximum payload which can be carried by this plane, while it provides sufficient operation and aerodynamics and approves its airworthiness. Maximum payload of the plane according to calculation is approximately 21tons.

2.8 Number of containers to be settled in the cargo holes

To estimate the number of containers that could be accommodated in such plane, we consider their weight and size.

1) According to weight: ratio between max payload of the airplane and gross weight of the ULD;

$$\frac{21000}{1588} = 13$$

2) According to size: ratio between respective dimension of cargo holes and ULD’s;

Table.2.4. number of LD3-45 placed in cargo holes

accordance	Main Deck	FWD	AFT
width	2	1	1
Length	8	3	4

Height	1	1	1
TOTAL	16	3	4
	23 containers can be placed in aircraft		

Comparing given numbers according to weight and size, generally, 13 containers can be distributed in all three compartments due to weight limitations; however it is possible to accommodate 16 containers in the main deck.

Conclusion to part 2

- A narrow-body passenger aircraft was converted to a cargo plane, which is spacious enough to carry 23 LD3-45 at the same time but because of loading limitations, that is 21 tons in this case, it is able to accommodate up to 13 containers in three cargo compartments only.
- A typical ULD for such prototypes(LD3-45) was described and necessary parameters of it were explained.
- Appropriate sizes were suggested for hatches and cargo holes taking into account some properties and factors.
- To keep the plane in well-operating zone and avoid overloading, consideration of center of gravity and maximum payload were represented.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

- Both cargo and passenger aircrafts have quiet similar parameters and characteristics.

- To accommodate two LD3 side by side in the main deck, less width of fuselage was used in the cargo aircraft.

- It seems that both aircrafts have the capacity to carry rather reasonable amount of payload in their category of utilization, regardless of the size, compared to other huge aircrafts.

- The amount of payload that the passenger aircraft can carry is rather profitable compared to cargo according to their field of use. However the cargo plane has enough interior space, so that dimensions of main deck could be greater than what we agreed about in this project. Hence I would propose to use such cargo planes to deliver good with light weight which require a large volume.

- Design of a floor system with high strength taking to account load applied to it from ULDs gives the possibility to fuselage to sustain more loads and decrease the fatigue effects on the fuselage structure during loading and unloading and presence of ULD in the cargo holes. There is the same condition for floor structure of passenger airplane as well; when weight of chairs, equipment, luggage and passengers vary every time.

- The coefficients and units used in the calculations are specific for systems that are used in the structure of planes. To increase the efficiency of the cargo plane i.e. increase the maximum payload, it is better to use elements in the systems of the aircraft with less mass coefficient(less weight) with same function which definitely needs application of advanced engineering compared to current technology applied.
- The other way for the same purpose (reduction of structural weight) is to build the fuselage, wing and other parts with light composite material which can protect and improve the performance of the plane.

The recommendations can be applied to both category of airplane, obviously.

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Appendix A

Project: Narrow-body Single-aisle Aircraft

National Aviation University

Aircraft design department

Project Diploma Calculation is done 04.06.2020

Performed by Askari Fatemeh

INITIAL DATA FOR CALCULATION WORK

Passenger Number 160

Flight Crew Number 2

Flight Attendant or Load Master Number 4

Mass of Operational Items 1692.69 kg

Payload Mass 17600 kg

Cruising Speed 840 km/h

Cruising Mach number 0.7831

Design Altitude 10.50 km

Flight Range with Maximum Payload 6000 km

Runway Length for the Base Aerodrome 2.95 km

Engine Number 2

Thrust-to-weight Ratio in N/kg 3.10

Pressure Ratio 32

Assumed Bypass Ratio 5.50

Optimal Bypass Ratio 5.50

Fuel-to-weight Ratio 0.24

Aspect Ratio 9.5

Taper Ratio 2.70

Mean Thickness Ratio 0.1

Wing Sweepback at Quarter Chord 25

High-lift Device Coefficient 0.97

Relative Area of Wing Extensions 0

Wing Airfoil Type supercritical

Winglets installed

Spoilers installed

Fuselage Diameter 3.95 m

Fineness Ratio 9.51

Horizontal Tail Sweep Angle 29deg

Vertical Tail Sweep Angle 34deg

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point 0.45286

Induce Drag Coefficient 0.00892

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

Cruising Mach number 0.78345

Wave Drag Mach number 0.80294

Calculated Parameter D_m 0.01989

Wing Loading in Pa (for Gross Wing Area):

At Takeoff 5667

At Middle of Cruising Flight 4781

At the Beginning of Cruising Flight 5481

Drag Coefficient of the Fuselage and Nacelles 0.00921

Drag Coefficient of the Wing and Tail Unit 0.00894

Drag Coefficient of the Airplane:

At the Beginning of Cruising Flight 0.02914

At Middle of Cruising Flight 0.02784

Mean Lift Coefficient for the Ceiling Flight 0.45286

Mean Lift-to-drag Ratio 16.26726

Landing Lift Coefficient 1.590

Landing Lift Coefficient (at Stall Speed) 2.385

Takeoff Lift Coefficient (at Stall Speed) 1.987

Lift-off Lift Coefficient 1.451

Thrust-to-weight Ratio at the Beginning of Cruising Flight 0.562

Start Thrust-to-weight Ratio for Cruising Flight 2.239

Start Thrust-to-weight Ratio for Safe Takeoff 2.832

Design Thrust-to-weight Ratio

$D_r = R_{cruise} / R_{takeoff}$ $R_{cruise} = 2.945$; $D_r = 0.791$

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

Takeoff 35.4243

Cruising Flight 58.9664

Mean cruising for Given Range 63.5477

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.03516
Block Fuel	0.24811

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.12542
Horizontal Tail	0.00961
Vertical Tail	0.00947
Landing Gear	0.03784
Power Plant	0.09050
Fuselage	0.08646
Equipment and Flight Control	0.12101
Additional Equipment	0.00983
Operational Items	0.01792
Fuel	0.30467
Payload	018633

Airplane Takeoff Weight 94454

Takeoff Thrust Required of the Engine	139.08
Air Conditioning and Anti-icing Equipment Weight Fraction	0.0207
Passenger Equipment Weight Fraction (or Cargo Cabin Equipment)	0.0137
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.0063
Furnishing Equipment Weight Fraction	0.0111
Flight Control Weight Fraction	0.0055
Hydraulic System Weight Fraction	0.0155
Electrical Equipment Weight Fraction	0.0317
Radar Weight Fraction	0.0030
Navigation Equipment Weight Fraction	0.0045
Radio Communication Equipment Weight Fraction	0.0023
Instrument Equipment Weight Fraction	0.0053
Fuel System Weight Fraction	0.0090
Additional Equipment: Equipment for Container Loading	0.0068
No typical Equipment Weight Fraction	0.0031
(Build-in Test Equipment for Fault Diagnosis, Additional Equipment of Passenger Cabin)	

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed 284.49 km/h

Acceleration during Takeoff Run 2.30

Airplane Takeoff Run Distance 1351 m

Airborne Takeoff Distance 578 m

Takeoff Distance 1930 m

CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed 270.26 km/h

Mean Acceleration for Continued Takeoff on Wet Runway 0.31

Takeoff Run Distance for Continued Takeoff

On Wet Runway 2188.19m

Continued Takeoff Distance 2766.57 m

Runway Length Required for Rejected Takeoff 2866.63 m

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight 73226 kg

Time for Descent from Flight Level till

Aerodrome Traffic Circuit Flight 19.4 min

Descent Distance 45.37 km

Approach Speed 257.28 km/h

Mean Vertical Speed 2.06 m/s

Airborne Landing Distance 520 m

Landing Speed 242.28 km/h

Landing run distance 806 m

Landing Distance 1326 m

Runway Length Required for Regular Aerodrome 2214 m

Runway Length Required for Alternate Aerodrome 1883 m