МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Кафедра конструкції літальних апаратів

«ДОПУСТИТИ ДО ЗАХИСТУ»
Завідувач кафедри
д-р техн. наук., проф.
_____________________С.Р.Ігнатович
(підпис)
« _____»___________________ 2022 р.

ДИПЛОМНИЙ ПРОЕКТ

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

Тема: «Аванпроєкт середньо магістрального пасажирського літака місткістю 150 пасажирів»

Виконав: ____________ **Лянцин ЧЗАН**

Керівник: д-р техн. наук., проф. ____________ **М.В. Карускевич**

Нормоконтролер: канд. техн. наук., доц.____________ **С.В. Хижняк**

Київ 2022

MINISRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

Aircraft Design Department

AGREED
Professor, Dr. of Sc.
_________S.R. Ignatovych
«___» _______ 2022

DIPLOMA WORK

(EXPLANATORY NOTE)

OF EDUCATIONAL DEGREE

«BACHELOR»

Theme: «Preliminary design of the mid-range passenger aircraft with 150 passengers capacity»

Performed by: ____________ **Liangqing Zhang**

Supervisor: Dr. of Science, Professor ____________ **M. V. Karuskevich**

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

Kyiv 2022

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty

Aircraft Design Department

Educational degree «Bachelor»

Speciality 134 "Aviation and Space Rocket Technology"

APPROVED
Professor, Dr. of Sc.
_________S.R. Ignatovych
«____ » ___________ 2022

TASK
for bachelor diploma work

1. Theme: «**Preliminary design of the mid-range passenger aircraft with 150 passengers capacity**»
   Confirmed by Rector's order from 10.05.2022 year № 489/ст from 10.05.2022
2. Thesis term: from 23.05.2022 to 19.06.2022
3. Work initial data:
   - Maximum payload – n = 150 passengers;
   - Flight range with maximum payload – L = 5000 Km;
   - Cruise speed – V_{cr} = 840 Km/h at operating altitude H = 10.5 Km;
   - Landing speed – V_{land} = 246.72 km/h.
4. Explanation notes (list of topics to be developed):
   - selection of design parameters;
   - choice and substantiations of the airplane scheme;
   - calculation of aircraft masses;
   - determination of basic geometrical parameters;
   - aircraft layout;
   - center of gravity position calculation;
   - determination of basic flight performance;
   - description of the aircraft design;

– engine selection;

– special part;

5. List of the graphical materials:

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

– layout of the airplane (A1×1);

– assembly drawing of the flexible conveyor (A0×1).

6. Calendar Plan

№ п/п	Task	Execution period	Signature
1	Task receiving, processing of statistical data	15.05.22	Liangqing Zhang
2	Aircraft take-off mass determination	19.05.22	Liangqing Zhang
3	Aircraft layout	19.05.22	Liangqing Zhang
4	Aircraft centering determination	25.05.22	Liangqing Zhang
5	Graphical design of the parts	25.05.22	Liangqing Zhang
6	Preliminary defence	14.06.22	Liangqing Zhang
7	Completion of the explanation note	20.06.22	Liangqing Zhang

7. Task date: 24.05.2022 year.

Supervisor of diploma work: ______________ M.V. Karuskevich
(signature)

Task is given for: Liangqing Zhang Liangqing Zhang
(signature)

ABSTRACT

Explanatory note to the diploma work «Preliminary design of the mid-range passenger plane with 150 passenger capacity» contains:

65 pages, 15 figures, 12 tables, 15 references and 3 drawings

Object of the design is development of the mid-range aircraft with 150 passengers capacity.

The aim of the diploma work is the preliminary design of the aircraft and its design characteristics estimation.

The methods of design are: analyzis of the prototypes and selection of the most advanced technical decisions to calculate the geometry for main parts of the fuselage, such as wing geometry calculation, tail unit geometry, fuselage layout and landing gear design. Besides center of gravity calculation is another significant portion in the design.

The diploma work contains drawings of the mid-range aircraft with 150 passengers, calculations and drawings of the aircraft layout, flexible conveyor concept, calculations and drawing.

AIRCRAFT, PRELIMININARY DESIGN, LAYOUT, CENTER OF GRAVITY POSITION, FLEXIBLE CONVEYOR.

				NAU 22 18 Z 00 00 00 04 KV			
Performed by	Liangqing Zhang	Liangqing Zhang		ABSTRACT	Letter	Sheet	Sheets
Supervisor	Karuskevich M.V.						
Adviser					402 AF 6.51101		
Stand.contr.	Khizhnyak S.						
Head of dep.	Ignatovych S.						

CONTENT

LIST OF ABBREVIATIONS

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

List of drawings

Format	№	Designation	Name	Quantity	Notes
			General documents		
A4	1	NAU 22 18Z 00 00 00 04 TW	Task for work	1	
	2	NAU 22 18Z 00 00 00 04	Mid-range passenger aircraft	2	
A1		Sheet 1	General view		
A1		Sheet 2	Fuselage layout		
A4	3	NAU 22 18Z 00 00 00 04 EN	Mid-range passenger aircraft	65	
			Explanatory note		
			Documentation for assembly units		
A0	1	NAU 22 18Z 00 00 00 04	Flexible conveyor drawing	1	

NAU 22.18Z.00.00.00.04 EN

Done by	Liangqing Zhang	Liangqing Zhang		Preliminary design of mid-range passenger aircraft with 150 passenger capacity (List of diploma work)	list	sheet	pages
Supervisor	Karuskevich					4	65
					ASF 402		
St.control.	Khyzhniak S.V.						
Head of dep.	Ignatovich S.R.						

Introduction

In today's economic development, we have realized that more and more people can choose a faster way to travel, and flying is the fastest way. In this context, passenger traffic has increased significantly. Airlines, in particular, have greatly increased the demand for passenger transport. In this regard, in order to be able to increase the company's profits, more medium-sized airliners are needed. Only in this way can we achieve stable profitability with higher reliability, higher stability and mid-range advantages in a highly competitive global market. Therefore, civil aviation needs new aircraft that meet the requirements of the International Air Transport Organization, in particular:

1. Higher flight safety performance;
2. Improve operating comfort;
3. A comfortable cabin that meets the highest requirements;
4. High reliability and easy operation.

After analyzing most of the aircraft currently in use in the aviation market, chose the Boeing 727-200 as the prototype because it is widely recognized in the civil aviation field.

At the same time, considering that the traditional conveying structure will cause damage to the body of the crew when transporting luggage on a civil airliner, I have improved the existing conveying mechanism and designed a flexible conveying mechanism to make the baggage check-in procedure easier.

As a means of transportation in the air, the aircraft will be subject to greater resistance during flight, and the lighter the weight of the aircraft, the greater the fuel utilization rate and the flight speed of the aircraft. In recent years, with the development and progress of society, lighter metals such as alloys are used in aircraft materials. While ensuring that the strength meets the requirements of aircraft design, the total weight of the aircraft is reduced as much as possible and the flight efficiency is improved.

PART 1. PRELIMINARY DESIGN OF THE AIRCRAFT

1.1. Choices of the projected data

Among the design requirements of modern civil aircraft, the most prominent is to ensure absolute safety, in addition to increasing comfortable flight experience and creating higher economic benefits. The design process of civil aircraft is a complex process, mainly for the The following steps:

Conceptual design→preliminary design→scheme review→detailed design→ design review → trial production test machine → design finalization → obtain airworthiness certificate→flight test→mass production.

At the same time, it is also very important to select appropriate parameters in the process of aircraft design, because various parameters will have different degrees of influence on the flight state during the flight of the aircraft. Therefore, in the preliminary design process of the aircraft in the first part, appropriate parameters should be selected at the beginning of the design.

The B727-200 was used as the prototype for this mission. It has a passenger capacity of 150-189. At the same time, in order to be able to compete with Airbus, the latest generation of avionics systems can be installed on the aircraft. Aircraft such as Boeing 727-100, Boeing 727-200, Boeing 727-200Adv will be mated to the designed aircraft in the category market. The detailed statistics of the prototype are shown in Table 1.1.

Table 1.1 – Operational-technical data of prototypes

Name of the prototype	**B727-100**	**B727-200**	**B727-200Adv**
Max payload	12927kg	24042kg	24042kg
Flight crew, [persons]	3	3	3
Passengers	131	189	189
Wing loading, [kN/m^2]	5.74	5.74	5.74
Mean cruising lift-to-drag ratio	14.79	14.79	14.79
Flight range with $G_{payload,max}$, [km]	4300	3100	3500
Range of cruising altitudes, [km]	11	13	13
$V_{cr\ max}$ / H, [km/h / km]	1102	1102	1102
$V_{cr,econ}$ / H, [km/h / km]	1000	1000	1000

Continuation of the table. 1.1.

Thrust/weight ratio kN/kg	2.4	2.9	2.9
Productivity	407	188	1237
Specific fuel consumption [kg/km]	4.73	6.91	6.94
Power plant data			
Number of engines and their type	3xJT8D-1	3xJT8D-9	3xJT8D-17R
Take off thrust, [kN]	62	64	77
`Cruising thrust, [kN]	19	20	24
Pressure ratio	31	31	31
Bypass ratio	5.5	5.5	5.5
Take off and landing characteristics			
Approach speed, [KIAS]	138	150	150
Landing speed, [KIAS]	132	137	137
Take off run distance, [m]	1030	1330	1030
Landing run distance, [m]	500	818	818
Take off distance, [m]	2500	3000	2600
Landing distance, [m]	2341	4236	4236
Airplane mass data			
Maximum Take off Mass, [kg]	77000	83800	95000
Landing Mass, [kg]	36560	44600	46700
Empty weight fraction, %	47.48	53.22	49.15
Fuel fraction, %	26.43	25.58	25.58
Payload fraction, %	16.79	28.69	25.31
Power plant weight fraction, %	7.95	5.21	4.93

The design scheme and specific layout of the aircraft are determined by the relative position, shape and quantity of each unit of the aircraft. The aerodynamic characteristics of the aircraft and the operational characteristics during flight depend on the aerodynamic shape, external layout and aerodynamic design of the aircraft. Fortunately, with the development of science and technology, the advanced avionics system of aircraft can improve the safety and stability of the aircraft during flight. In addition to this, the economic efficiency of the aircraft can also be greatly improved.

1.2. Brief description of the aircraft

The aircraft is a medium-range three-engine narrow-body passenger aircraft, using Pratt & Whitney JT8D engine, using T-shaped tail, the engine is placed behind the fuselage, of which the No. 2 engine is placed above the fuselage and below the tail, and the engine is connected by an S-shaped tube And air intake.

The aircraft is designed for smaller airports, so independence from ground facilities is an important requirement, so it has one of the most notable features: the built-in stairs that open from the abdomen of the fuselage can initially be opened in flight. At the same time, the aircraft adopts a brand-new digital flight control system, which can extend its static stability during flight.

As well as short field capabilities, the aircraft is able to operate into and out of gravel runways as well. Due to the engines being mounted much higher on the fuselage, they were further away from foreign objects being ingested than those of aircraft with engines slung under the wing. In addition, It was added brakes to the nose wheels so as to give more positive control and stopping power ability.

Fuselage. The fuselage structure is a full metal beam stringer (such as a semi-monocoque type). This type of structure is characterized by a relatively thick skin and supported by longitudinal beams and frames.

The fuselage reasonably combines the shape and elongation of the aircraft components, so that the drag generated by the aircraft in this situation is as low as possible, and the critical value M is higher, etc

There are seats for the first and second pilots in the cockpit. The main pilot is on the left side of the aircraft, and the co-pilot is on the right. The flight instrument panel is installed in front of the pilot, and an airplane console is installed between the two pilots. There is an upper electric switchboard above the glass of the cockpit canopy. The left side of the fuselage is the main driver's side console, and the right side is the co-pilot's test console.

Wing. The wing adopts three-slit trailing edge flaps, inner leading edge Kruger flaps, and outer leading edge slats. The aircraft can fly at 0.9 times the speed of sound at high altitude. Therefore, the three-slit flaps and wind-resistance flaps that increase the lift efficiency can increase the wing surface area by 25% to meet the requirements of low-speed approach and short-field takeoff and landing.

The wing adopts a cantilevered mid-lower single wing. It uses a supercritical rear-loaded airfoil similar to the prototype, which can adapt well to the characteristics of a short average range. The fuel tank is installed under the wings on both sides.

The wing is mainly loaded by ribs, longitudinal beams, beams and skin. The distance between the lower wing and the ground is relatively small. When the landing gear is retracted, the wings on both sides will sense energy to reduce the impact on the cabin, and can provide additional buoyancy when landing on water.

The aircraft is equipped with oversized landing gear to reduce ground load and enable it to operate on the same runway. Compared with most passenger planes, the soft oleo struts (shock absorbers) provide a smoother ride on bumpy airports.

When the landing gear is retracted, it is less harmful to the aircraft and passengers; when the landing gear is retracted, the wing senses the impact energy and protects the passenger cabin; when boarding, it is immersed in the water along the wing to give the fuselage extra buoyancy.

The wing is swept back, so it has a larger M_{cr} and a weaker wave crisis, also come out many disadvantages:

-Large take-off and landing speeds, so long run lengths are required.

-There is a tendency to end the flow of the wings.

-The lowest coefficient of maximum lift.

-Lateral stability decreases as $M > M_{max}$.

Tail unit. The aircraft adopts a swept rear wing, and because three engines are installed on the rear of the fuselage, it adopts a T-tail layout. The tail is composed of a vertical tail and a horizontal tail. This type of tail can provide higher stability and maneuverability at a lighter weight. The vertical stabilizer includes a fixed vertical stabilizer and a movable rudder, while the horizontal stabilizer includes a horizontal stabilizer and elevator. The sweep angle of the vertical tail and the horizontal tail is greater than the sweep angle of the wing. As the aircraft's flight speed increases, the aerodynamic characteristics of the tail are more stable than that of the wings.

The contours of the horizontal tail and the vertical tail are symmetrical. In a symmetrical section, rudders in different directions can maintain the same aerodynamic load characteristics during deflection, and have less resistance. The vertical tail has a larger profile and relative thickness than the horizontal tail, which can reduce the mass of the stabilizer from the vertical and horizontal tails.

Crew cabin. The configuration of the pilot's workplace can ensure the safety of the pilots and flight attendants, and ensure the control of the aircraft in dangerous situations. The design, performance and automation of navigation equipment and airborne systems, and the structure and settings of the display system equipment enable the pilot to complete various tasks without exceeding the existing load requirements.

A cone-shaped windshield is installed in the cockpit of the aircraft to enable pilots to observe the outside world easily and to prevent accidents that directly harm the human body such as high-speed air currents or bird strikes. It provides pilots with a broad field of vision and meets the flight performance requirements under expected conditions. The streamlined fairing conforms to the laws of fluid mechanics, which can minimize drag and protect the equipment and various equipment inside the aircraft. The pilot can carry out manual and automatic control from any position, which greatly improves the maneuverability of the flight.

Place the light on the top of the control panel. In the most accessible area, there is a quick control panel to control the radio station and automatic control system.

On the upper control panel of the transportation system, there are power, fuel, air conditioning, hydraulic, anti-icing, engine and APU boards, alarm boards and fire extinguishing switches.

All configurations are in strict compliance with international airworthiness standards.

1.3. Main parts of the aircraft calculations

In the calculation part of the aircraft, it is necessary to carry out: the size calculation of the main part of the aircraft, the calculation of the main structure of the aircraft, the calculation of the load of the main parts of the aircraft, and the calculation of the overall center of gravity of the aircraft. In addition, the calculation of the internal layout of the aircraft is also required: the layout of the cabin, the calculation of other equipment in the aircraft (galley, lavatory, etc.).

All designs and calculations should comply with international airworthiness regulations. All calculation data will be presented in the appendix.

1.3.1. Wing geometry calculation

The geometric properties of the wing are determined by the weight m_0 and the specific wing load P_0.

The area of full wing is:

$$S_{wfull} = \frac{m_0 \cdot g}{P_0} = \frac{75467 \cdot 9.8}{5.741} = 128.82 m^2$$

Wing span is:

$$l = \sqrt{S_w \cdot \lambda_w} = \sqrt{128.82 \cdot 9.5} = 34.98 m$$

Wing chord is:

$$c_{wing} = \frac{l}{\lambda_w} = \frac{34.98}{9.5} = 3.68 m$$

Root chord is:

$$b_0 = \frac{2S_w \cdot \eta_w}{(1+\eta_w)\cdot l} = \frac{2\cdot 128.82\cdot 4.2}{(1+4.2)\cdot 34.98} = 5.95m$$

Tip chord is:

$$\mathrm{b_t} = \frac{b_0}{\eta_w} = \frac{5.95}{4.2} = 1.42m$$

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

$$c_i = c_w \cdot b_t = 0.11\cdot 1.42 = 0.156m$$

On board chord for trapezoidal shaped wing is:

$$b_{ob} = b_0 \cdot \left(1 - \frac{(\eta_\mathrm{w} - 1)\cdot D_f}{\eta_w \cdot l_w}\right) = 5.95\cdot\left(1 - \frac{(4.2-1)\bullet 4.2}{4.2\bullet 34.98}\right) = 5.41m$$

When determining the wing configuration, first determine the size and location of each component (stringer, spar, etc.)

The location of the average aerodynamic chord length can be plotted according to the method of determination of the average aerodynamic chord length(figure 1.1). At the same time, the average aerodynamic chord length can be calculated according to the following methods:

$$b_{MAC} = 4.15m$$

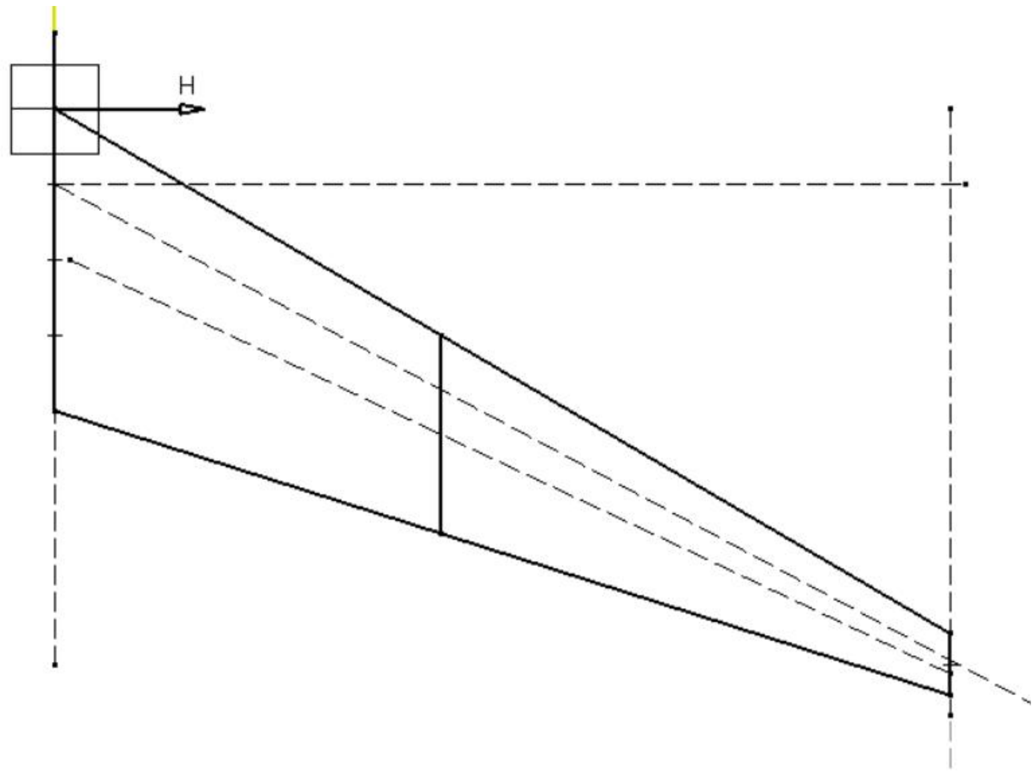

Figure 1.1 – Determination of mean aerodynamic chord

Next, calculate the geometric parameters of the ailerons and high-lift devices.

Ailerons geometrical parameters are determined in next consequence:

Ailerons span:

$$l_{ai} = 0.375 \cdot \frac{l_w}{2} = 0.375 \cdot \frac{34.98}{2} = 6.56m$$

Aileron area:

$$S_{ail} = 0.065 \cdot \frac{S_w}{2} = 0.065 \cdot \frac{128.82}{2} = 4.19m^2$$

Aileron chord:

$$c_{ail} = 0.22...0.26 \cdot c_{wing} = 0.23 \cdot 3.68 = 0.85m$$

Balance tap area:

$$S_{bal \cdot tap} = (0.04...0.06) \cdot S_{ail} = 0.05 \cdot 0.85 = 0.04m^2$$

Chord of slat:

$$c_{slat} = (0.1...0.15) b_0 = 0.13 \cdot 5.95 = 0.77m$$

Chord of flap:

$$c_{flap} = (0.3...0.4) \cdot c_{wing} = 0.35 \cdot 3.68 = 1.29m$$

The relative wingspan and aileron area of the new generation design aircraft are smaller than the second generation aircraft. So, l_{ail} = 0.122. At the same time, spoilers and ailerons are applied simultaneously in the wing design, so that lateral control of the aircraft can be achieved. In the new generation of aircraft, it is also particularly important to optimize the characteristics of the aircraft during take-off and landing, which can be achieved by increasing the span and area of high-lift devices.

Aerodynamic compensation of the aileron.

Axial $S_{axinail} \leq (0.25…0.28)\ S_{ail} = 0.26 \cdot 4.19 = 1.09m^2$

Inner axial compensation $S_{inaxinail}$ = (0.3..0.31) S_{ail};

Area of ailerons trim tab.

For three engine airplane: $S_{tail} = 0.05...0.06 \cdot S_{ail} = 0.05 \cdot 4.19 = 0.21m^2$

Range of aileron deflection

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

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

In the previous task, the appropriate wing layout and lift device have been determined, so we can roughly determine the lift coefficient of the aircraft during takeoff and landing.

To determine the lift coefficient, it can be calculated by the following formula: $\Delta C_{y\max} = (\frac{C_{y\max l}}{C_{y\max bw}})$

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

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

b_s = 0.1..0.15 – slats.

Effectiveness of high-lift devices (C^*_{ymaxl}) rises proportionally to the wing span increase, serviced by high-lift devices, so we need to obtain the biggest span of high lift devices ($l_{hld} = l_w - D_f - 2l_{ail} - l_n$) due to use of flight spoiler and maximum diminishing of the are of engine and landing gear nacelles.

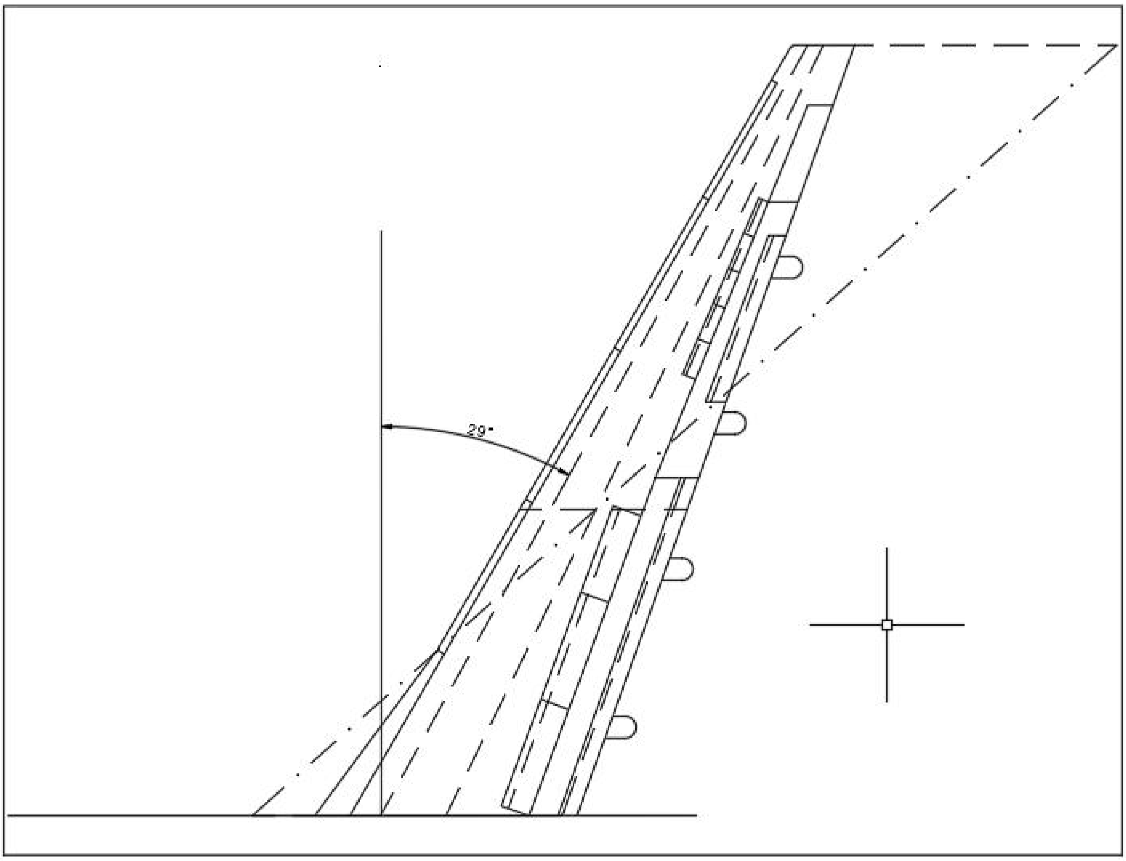

Figure 1.2 – Top view of aircraft wing structure

1.3.2. Fuselage layout

Since the cross-section of the fuselage will generate a certain flight resistance during the flight, the aerodynamic characteristics of the cross-section of the fuselage should also be carefully considered in the design process.

Since wave drag has no effect on subsonic aircraft, we only need to consider friction drag C_{xf} and profile drag C_{xp}.

During flight, the wave resistance C_{xw} will be affected by the shape of the front part of the aircraft. In order to more likely reduce the impact of wave resistance on the aircraft during flight, the shape of the nose is circular.

At the same time, an important point in the design of the fuselage is to consider the requirements of the strength of the fuselage. First of all, it is necessary to pass the requirements of the load applied to the fuselage during the experiment, and to ensure that the load that the aircraft can bear during the flight is met.

The fuselage cross-section design uses a circular cross-section, which can reduce the overall weight of the aircraft as much as possible, and minimize the width of the aircraft skin. The partial part of the fuselage uses a combination of two or more circles.

In the fuselage design process, the important parts are: fuselage diameter; fuselage length; fuselage aspect ratio; fuselage nose part aspect ratio; tail unit aspect ratio.

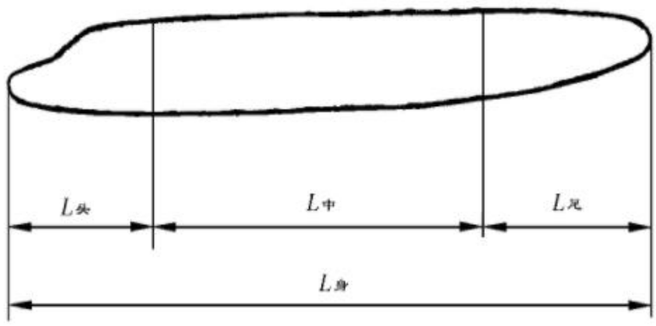

Figure 1.3 – Split the three-section structure of the fuselage(the length of the nose part, central part and rear part of the fuselage

Fuselage length is equal:

$$l_f = FR \bullet D_f = 9.6 * 4.2 = 40.32m$$

Fuselage forward part is equal:

$$l_{fwd} = l_f \bullet \frac{10}{88} = 40.32 \bullet \frac{10}{88} = 4.58m$$

Fuselage nose part aspect ratio is equal:

$$\lambda_{fwd} = \frac{l_{fwd}}{D_f} = \frac{4.58}{4.2} = 1.1$$

Fuselage after part is equal:

$$l_{aft} = l_f \bullet \frac{12}{88} = 40.32 \bullet \frac{12}{88} = 5.5m$$

Fuselage mid part is equal:

$$l_{mid} = l_f - l_{fwd} - l_{aft} = 40.32 - 4.58 - 5.5 = 30.24m$$

In the fuselage length design process, we first determine the cabin height, and then use this height to design the size of the mid-section of the fuselage.

I choose the next parameters:

Cabin height is equal:

$$H_{cab} = 1.48 + 0.17B_{cab} = 1.48 + 0.17 \bullet 4.2 = 2.194m$$

For economic and business cabin with the scheme of allocation of seats in the one row (3 + 3)

For three seats of one block distribution we may take the width as: (3*3)

economic class seat width $b_{3ec}=1455.....1650mm$;

business class seat width $b_{3bu}=1500.....1770mm$;

The distance from the outside of the seat handle to the inner wall of the fuselage $\delta_1=40.....50mm$;

The distance between inner and outer walls of the fuselage $\delta_{wall}=80.....120mm$;

For aisle width we may take as:

$b_{ais\text{-}ec}$=*400.....510mm;*

$b_{asi\text{-}bu}$=*500.....600mm;*

The appropriate width of the economic cabin is equal:

$$B_{cab.eco} = n_3 \bullet B_{3seat} + B_{aisle} + 2\delta_{wall} + 2\delta_L = 1650 \bullet 2 + 510 + 2 \times 120 + 2 \times 50 = 4.15m$$

For business cabin with the scheme of allocation of seats in the one row (3 + 3)

The appropriate width of the business cabin is equal:

$$B_{cab.bus} = n_3 \bullet B_{3seat} + B_{aisle} + 2\delta_{wall} + 2\delta_L = 1700 \bullet 2 + 600 + 2 \times 50 + 2 \times 50 = 4.2m$$

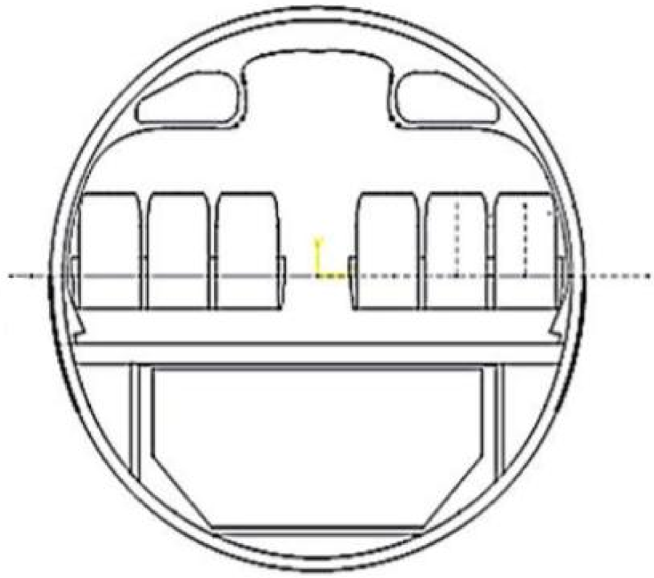

Figure 1.4 – Cross-sectional display of the fuselage cabin

Of all the shape settings, the circular section is undoubtedly the most stable and uses the least amount of material. Because of the layout of passengers and cargo in the cabin, a circular cross-section is not the most suitable. Therefore, try to use an ellipse or a shape design where two circles meet. But the ellipse faces other problems in the production process, such as the upper and lower parts are bent due to excessive pressure, so other structures are needed to enlarge it.

Step of normal bulkhead in the fuselage construction is in the range of 360...500mm.

The window layout of the cabin is one row on each side of the fuselage. The window shape is a rectangle with rounded corners. The windows correspond to the cabin wall steps and are 500...510mm in size.

Next， the task is the calculation of the length of the passenger cabin. The seat allocation of economy class (3+3) and business class (3+3), so economy class can be arranged with 120 passenger seats (20 rows), and There are 30 seats in business class (5 rows in total), and the seat spacing can be determined by cruise time and other parameters. (as shown in Figure 1.5):

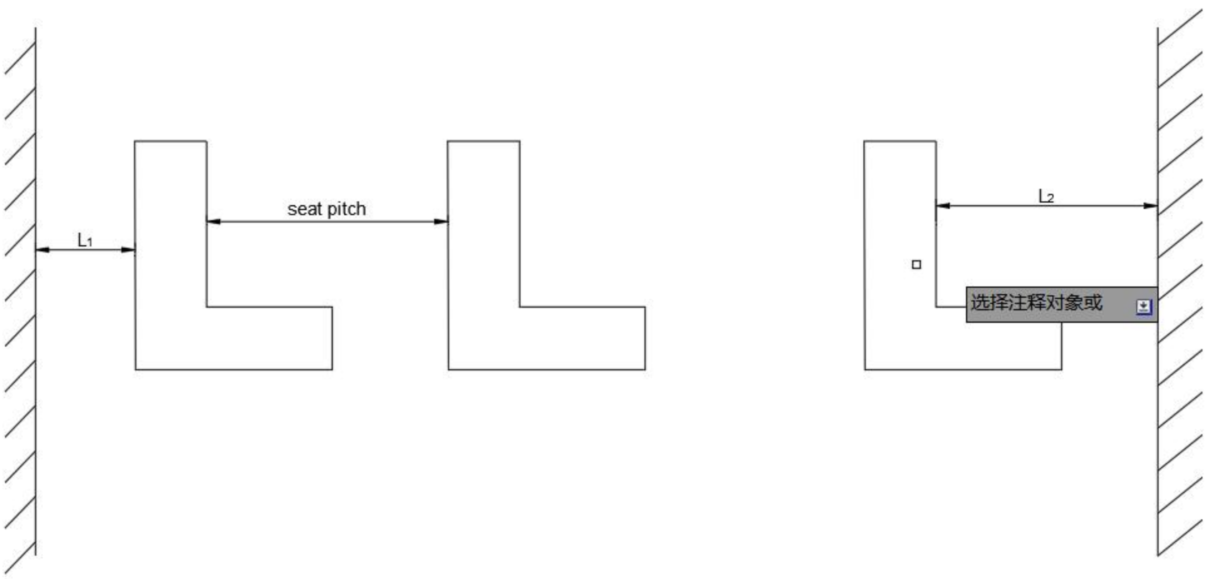

Figure 1.5 – Seat pitch dimension

L_1=250mm

L_2=1200.....1300mm

Seat pitch select(shown at table 1.2).

Table 1.2 – Seat pitch selection reference table

type of class	less than 3hours	more than 3hours
first	1020	1080
business	960	960
economic	810	870

The length of economic passenger cabin is equal:

$$L_{cab.eco} = L_1 + (n_{rows} - 1) \bullet L_{seatpitch} + L_2 = 1200 + (20 - 1) \bullet 960 + 250 = 22070 mm$$

The length of business passanger cabin is equal:

$$L_{cab.bus} = L_1 + (n_{rows} - 1) \bullet L_{seatpitch} + L_2 = 1200 + (5 - 1) \bullet 960 + 250 = 5290 mm$$

1.3.3. Luggage compartment

Given the fact that the unit of load on floor K = 400… 600 kg/m2

The area of cargo compartment is defined:

$$S_{cargo} = \frac{M_{bag}}{0.4K} + \frac{M_{cargo\&mail}}{0.6K} = \frac{20 \bullet 150}{0.4 \bullet 600} + \frac{15 \bullet 150}{0.6 \bullet 600} = 18.75 m^2$$

Cargo compartment volume is equal:

$$V_{cargo} = v \bullet n_{pass} = 0.2 \bullet 150 = 30 m^3$$

Luggage compartment design similar to the prototype

1.3.4. Galleys and buffets

According to airworthiness regulations, there must be multiple kitchens on the aircraft for storing food, and the cabinets in the kitchen must be placed at the door of the kitchen. At the same time, if the flight time is more than 3 hours, sufficient water and food must be provided for passengers. Based on cruising speed and range, the class approximates the total amount of food, packaging and cupboard storage required for a single trip per passenger to be 0.11 cubic meters.Now we will calculate the parameters of galleys.

$V_{gally}=(0.1.....0.12)n_{pass}$

Volume of buffets(galleys) is equal:

$$V_{galley} = 0.11 \bullet 150 = 16.5m^3$$

Area of buffets(galleys) is equal:

$$S_{galley} = \frac{V_{galley}}{H_{cab}} = \frac{16.5}{2.194} = 7.52m^2$$

Area of the floor for wardrobe is equal:

$$S_{war}=(0.035.....0.04)n_{pass}=0.036\times150=5.4\text{m}^2$$

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

zBuffet design similar to prototype.

1.3.5 Lavatories

Number of toilet facilities is determined by the number of passengers and the time of flight : when time is more than 4h, one toilet for 40 passengers; and if t=2.....4 hours, one for 50 passengers; if t < 2 hours , one for 60 passengers.The aircraft has a total of four toilets, two are located in the nose of fuselage which directly between the cockpit and business class, and another two are located in the after compartment of the fuselage.The number of lavatories I choose according to the original airplane and it is equal:

$$n_{lav} = 4$$

Area of lavatory:

$$S_{lav} = 1.5m^2$$

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

1.3.6. Layout and calculation of basic parameters of tail unit

In the process of designing the aerodynamic layout of the aircraft, one of the most important tasks is the choice of the tail unit layout. In order to ensure the longitudinal stability of the aircraft in an overload situation, the center of gravity of the tail wing should be located in front of the focus of the aircraft. The distance between this is affected by the average value of the aerodynamic chord of the wing and also determines the ratio of longitudinal stability.

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

m^{Cy}_x –is the moment coefficient; x_T. x_F- center of gravity and focus coordinates. If m^{Cy}_x=0, the plane has the neutral longitudinal static stability, if m^{Cy}_x>0, then the plane is statically instable.

The values of L_{htu} and L_{vtu} depend on several factors. At the same time, they are affected by the length of the front and rear of the fuselage and the position of the swept wings, and the stability and control conditions of the aircraft. This is determined according to the parameters of the prototype and the related proportions.

Determination of the tail unit geometrical parameters

Area of vertical tail unit is equal:

$$S_{VTU} = (0.12...0.2)S_{wing} = 0.15 \bullet 128.82 = 19.32m^2$$

Area of horizontal tail unit is equal:

$$S_{HTU} = (0.18...0.25)S_{wing} = 0.2 \bullet 128.82 = 25.76m^2$$

Chose the Length of the tail unit.

$$A_{HTU} = 0.65...0.8, A_{VTU} = 0.08...0.12$$

Length of horizontal tail unit is equal:

$$L_{HTU} = \frac{A_{HTU} \cdot S_{wing} \cdot b_{MAC}}{S_{HTU}} = \frac{0.7 \cdot 128.82 \cdot 4.15}{25.76} = 14.53m$$

Length of vertical tail unit is equal:

$$L_{VTU} = \frac{A_{VTU} \cdot S_{wing} \cdot b_{MAC}}{S_{VTU}} = \frac{0.1 \cdot 128.82 \cdot 4.15}{19.32} = 2.77\ m$$

The length of the nose and fuselage tail, the wing position and sweep angle, and the stability and control conditions of the aircraft all have an effect on the L_{htu} and L_{vtu}.

Determination of the elevator area and direction:

Altitude elevator area:

$$S_{el} = 0.2765 \bullet S_{HTU} = 0.2765 \bullet 25.76 = 7.12 m^2$$

Rudder area:

$$S_{rud} = 0.2337 \bullet S_{VTU} = 0.2337 \bullet 19.32 = 4.52 m^2$$

Choose the area of aerodynamic balance.

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

Elevator balance area is equal:

$$S_{eb} = (0.22...0.25)S_{el} = 0.24 \cdot 7.12 = 1.71\ m^2$$

Rudder balance area is equal:

$$S_{rb} = (0.2...0.22)S_{rud} = 0.21 \cdot 4.52 = 0.95\ m^2$$

The area of altitude elevator trim tab:

$$S_{te} = 0.08 \cdot S_{el} = 0.08 \cdot 7.12 = 0.57\ m^2$$

Area of rudder trim tab is equal:

$$S_{tr} = 0.06 \cdot S_{rud} = 0.06 \cdot 4.52 = 0.271\ m^2$$

Root chord of horizontal stabilizer is:

$$b_{oHTU} = \frac{2S_{HTU} \bullet \eta_{HTU}}{(1+\eta_{HTU}) \bullet l_{HTU}} = \frac{2 \bullet 25.76 \bullet 3.25}{(1+3.25) \bullet 14.53} = 2.71$$

Tip chord of horizontal stabilizer is:

$$b_{0HTU} = \frac{b_{OHTU}}{\eta_{HTU}} = \frac{2.71}{3.25} = 0.83$$

Root chord of vertical stabilizer is:

$$b_{oHTU} = \frac{2S_{VTU} \bullet \eta_{VTU}}{(1+\eta_{VTU}) \bullet l_{VTU}} = 4.3$$

Tip chord of vertical stabilizer is:

$$b_{0VTU} = \frac{b_{OVTU}}{\eta_{VTU}} = 0.994$$

1.3.7. Landing gear design

In the preliminary design process of the aircraft, the most basic is to determine the center of gravity of the aircraft. Since the whole picture of the aircraft has not been determined, only some parameters of the landing gear of the aircraft can be determined first.

The aircraft is equipped with a tricycle with retractable landing gear (fig.1.6). The landing gear is powered by hydraulic system A, or it can be extended manually. When the landing gear is extended, the main wheel and front wheel door are closed. During normal operation, the wheel well doors will only be opened when the landing gear is in transit. The sequence valve opens the gear door, extends or retracts the gear, and then closes the door. The manual gear door release mechanism is located in each main wheel well for maintenance and inspection of the wheel well.

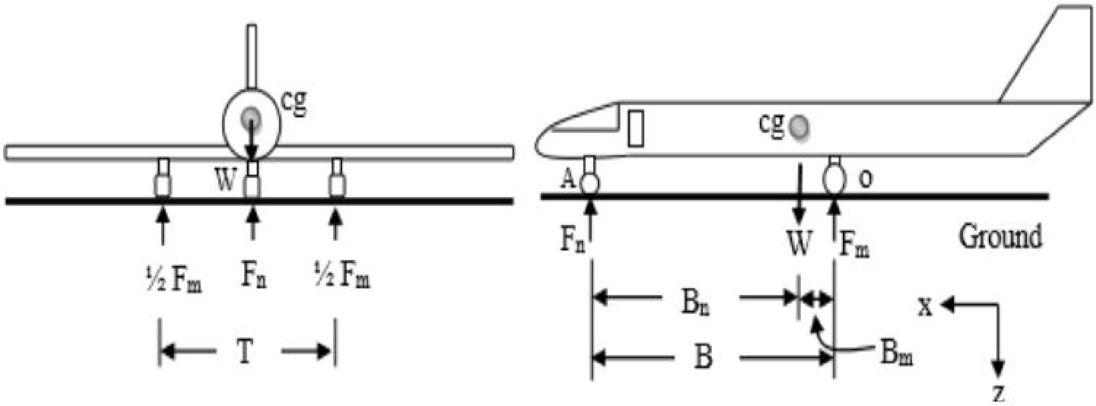

Figure 1.6 – Schematic diagram of aircraft landing gear length

Main wheel axel offset is:

$$B_m = (0.15...0.2)b_{MAC} = 0.18{\cdot}4.15 = 0.747\ m$$

When the wheel-axle offset is too large, the lift of the landing gear before take-off is complicated. When the axle offset is too small and the load of the aircraft tail unit occurs first, the aircraft tail unit will drop.

Landing gear wheel base comes from the expression:

$$B = (0.3...0.4)l_f = 0.35{\cdot}40.32 = 14.11\ m$$

Large value belongs to the airplane with the engine on the wing.

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

Front wheel axial offset will be equal:

The distance from the centre of gravity to the nose LG

$$B_n = B - B_m$$

$$B_n = 14.11 - 0.747 = 13.363\ m$$

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

In this mission, the dimensions of the landing gear tires were determined based on the take-off weight of the aircraft and the loads it received during take-off and landing, and a dynamic loading experiment was also performed on the nose gear.

The pneumatic device that powers the landing gear and the pressure inside the device are determined by the runway surface on which the aircraft operates, and brakes are installed on the main tires and sometimes the front tires for practical reasons.

The load on the wheel is determined:

K_g = 1.5...2.0 – dynamics coefficient.

Nose wheel load is equal:

$$F_{NOSE} = \frac{B_m \cdot m_0 \cdot 9.81 \cdot K_g}{B \cdot Z} = \frac{0.747 \cdot 75467 \cdot 9.81 \cdot 2}{14.11 \cdot 2} = 39.2\ KN$$

Main wheel load is equal:

$$F_{main} = \frac{(B - B_m) \cdot m_0 \cdot 9.8}{B \cdot n \cdot z} = \frac{13.363 \cdot 75467 \cdot 9.81}{14.11 \cdot 2 \cdot 2} = 175.3\ KN,$$

where n, and z – is the quantity of the supports and wheels on the one leg.

By calculated F_{main} and F_{nose} and the value of V take off and Vl_{anding}, pneumatics is chosen from the catalog, the following correlations should correspond.

$P^K_{slmain} \geq P_{main}$; $P^K_{slnose} \geq P_{nose}$; $V^K_{landing} \geq V_{landing}$; $V^K_{take\ off} \geq V_{take\ off}$

Where--- K is the index designated the value of the parameter allowable in catalog.

The common classification of aircraft tires is the type classified by the American Tire and Rim Association. On airplanes, I choose radial airplane tires (three-piece). All new sizes under development are in this category. At the same time, the design can meet the requirements of the highest speed and load in the current operating aircraft, and is the most advanced design of the tires used by the aircraft. (As shown in Figure 1.7)

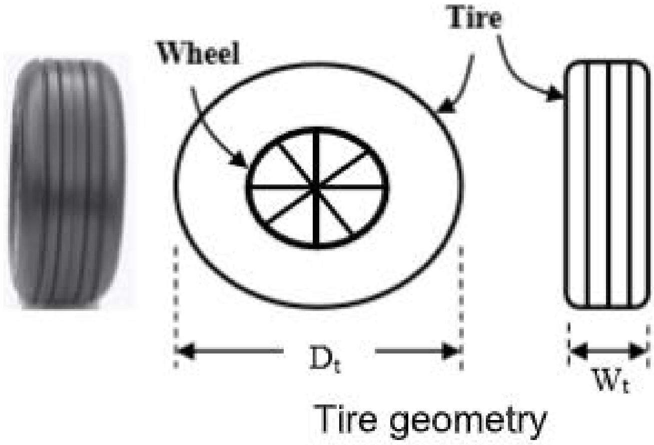

Figure 1.7 – Tire principle dimensions

Table 1.3 – Aviation tires for designed aircraft

Main gear		Nose gear	
Tire size	Ply rating	Tire size	Ply rating
1741x 501mm	18	1543x470 mm	12

As for brakes, we choose the disc brakes, there are superior performance, are lighter, and easier to maintain.

1.3.8. Choice and description of power plant

Refer to the B727 prototype, which uses the P&WJT8D-9 engine (table 1.4). Three engines are installed at the rear of the fuselage, and the engines use wide-chord hollow blades without bosses. With the characteristics of "floating wall" combustion and efficient fuel rate, each engine has a digital full-power electronic throttle control system and reverse thrust.

Table 1.4 – Examples of application P&WJT8D

Model	Thrust	Bypass ratio	Dry weight
P&WJT8D-1	14000 lbf (62 kN)	1.74	2048 kg
P&WJT8D-9	14500 lbf (67 kN)	1.07	1454 kg
P&WJT8D-17R	17400 lbf (77 kN)	0.96	1560 kg

1.4. Center of gravity calculation

1.4.1. Trim-sheet of the equipped wing

When we consider the weight of the aircraft wing position: including the weight of the wing structure, the weight of the internal equipment of the wing (hydraulic control system, electrical system, etc.), the weight of fuel.

And the landing gear part of the aircraft: no matter what the layout of the landing gear is and where it is installed, its mass should be included in the total mass of the wing. The method of determining the center of mass of the aircraft is: take the horizontal reference plane where the intersection of the average aerodynamic chord length of the wing and the leading edge of the wing is located, and the projection on this surface is the center of mass of the aircraft. Taking this point as the origin, the coordinates of the tail of the wing are positive, and the coordinates of the head of the wing are negative.

The mass of AC is 91295 kg. Coordinates of the center of power for the equipped wing are defined by the formulas:

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

Table 1.5 - Trim sheet of equipped wing

N	Object name	Mass		C.G coordinates Xi,m	Mass moment, Xi*mi
		units	total mass m(i)		
1	Wing (structure)	1.000.11	8265.15	1.87	15435.16
2	Fuel system	0.0084	633.92	1.87	1183.85
3	Airplane control, 30%	0.0019	142.63	2.49	355.16
4	Electrical equipment, 10%	0.0033	245.27	0.42	101.79
5	Anti-ice system, 50%	0.0112	845.23	0.42	350.77
6	Hydraulic system, 70%	0.0120	903.34	2.49	2249.32
7	Power plant 1,3	0.0627	4730.77	-1	-4730.77
8	Equipment wing without landing gear and fuel	0.2089	15766.31	0.95	14945.26
9	Nose landing gear	0.0078	586.98	-11.62	-6820.73
10	Main landing gear	0.0311	2347.93	2.49	5846.34
11	Fuel	0.2857	21559.41	1.87	40262.20
	Total	0.5335	40260.64	1.35	54233.08

1.4.2. Trim-sheet of the equipped fuselage

The example list of the objects for the AC, which engines are mounted under the wing, is given in table 1.6.

The CG coordinates of the FEF are determined by formulas:

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

After we have determined the C.G., the moment balance equation for the fuselage nose can be constructed:

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

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

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

where $\boldsymbol{m_0}$ – aircraft takeoff mass, kg; $\boldsymbol{m_f}$ – mass of fully equipped fuselage, kg; $\boldsymbol{m_w}$ – 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) $\mathbf{B_{MAC}}$ –low wing ;

Table 1.6 – Trim sheet of equipped fuselage

N	Object names	Mass		C.G coordinates Xi,m	Mass moment, Xi*mi
		units	total mass m(i)		
1	Fuselage	0.091	6836.56	20.16	137824.96
2	Power plant 2	0.031	2365.39	34.82	82362.79
3	Horizontal tail	0.0099	747.88	43.44	32487.82
4	Vertical tail	0.0098	742.60	38.89	28879.53
5	Radar	0.0032	241.50	0.73	176.29
6	Radio equipment	0.0024	181.12	2.75	498.08
7	Instrument panel	0.0055	415.07	2.63	1091.63
8	Navigation equipment	0.0047	354.70	8	2837.56
9	Flight control system 70%	0.0044	332.81	20.16	6709.44
10	Hydraulic system 30%	0.0051	387.15	28.22	10926.80
11	Electrical equipment 90%	0.0293	2207.41	20.16	44501.38

12	Not typical equipment	0.0037	279.23	33	9214.52

Continuation of the table. 1.6.

1	Lining and insulation	0.0090	679.20	20.16	13692.73
14	Anti-ice system 25%	0.0056	422.62	32.26	13631.88
15	Airconditioning system 25%	0.0056	422.62	20.16	8519.92
16	Passenger seats (business class) 1 seat/block of 2/block of 3/ 8-10kg/14-18kg/20-25kg	0.0032	240	8.99	2157.60
	Passenger seats (economy class) 1 seat/block of 2/block of 3/ 6-8kg/12-15kg/18-20kg	0.0095	720	24	17280
	Seats of flight attendances	0.0002	16	17.4	278.4
	Seats of pilots	0.0004	32	3.95	126.4
	Emergency equipment	0.0027	207.02	21.47	4444.00
17	Lavatory 1	0.0020	150.93	5.88	887.49
	Lavatory 2	0.0020	150.93	29.26	4416.33
	Lavatory 3	0.0020	150.93	29.26	4416.33
	Galley 1	0.0020	150.93	12.05	1818.75
	Galley 2	0.0020	150.93	12.05	1818.75
18	Operational items	0.0195	1470.10	6	8820.58
19	Additional equipment	0.0037	276.96	6	1661.78
20	Equipped fuselage without payload	0.2694	20332.5707	21.71303193	441481.7567
21	Passengers(economy)	0.1193	9000	24	216000
22	Passengers(business)	0.0298	2250	8.99	20227.5

23	On board meal	0.0030	225	12.05	2711.25
24	Baggage	0.0133	1000	24	24000

Continuation of the table. 1.6.

25	Cargo， mail	0.0265	2000	11.28	22560
26	Flight attendant	0.0032	240	17.4	4176
27	Crew	0.0020	154	3.95	608.3
28	**TOTAL**	0.4664	35201.57	20.79	731764.81

According to the table 1.6:

$$X_f = \frac{\Sigma m_{i'} x_{i'}}{\Sigma m_{i'}} = 20.788$$

$$X_{MAC} = \frac{mf\ xf + mw * x'w - moC}{mo - mw} = 20.371$$

1.4.3. Calculation of center of gravity positioning variants

The list of mass objects for centre of gravity variant calculation given in table 1.7 and Center of gravity calculation options given in table 1.8, completes on the base of both previous tables.

Table 1.7 – Calculation of C.G. positioning variants

1	Name	Mass, Kg	Coordinate	Mass moment
2	Object	mi	C.G., M	Kg.m
3	Nose landing gear (extended)	586.98	7.02	4120.62
4	Main landing gear (extended)	2347.93	23.56	55317.21
5	Equipped wing (without fuel and landing gear)	15766.31	21.32	336125.19
6	Fuel for flight	18724.12	22.24	416401.44

7	Fuel reserve	2834.54052	22.23877527	63036.70963
8	Equipped fuselage (without payload)	20332.5707	21.71303193	441481.7567

Continuation of the table. 1.6.

9	Passengers of business class	2250	8.99	20227.5
10	Passenger of economy class	9000	24	216000
11	Baggage	3000	24	72000
12	Cargo， mail	1000	11.28	11280
13	Galley (meal)	301.87	12.05	3637.51
14	Flight attendant	240	11.89	2853.6
15	Crew	154	4	616
16	Nose landing gear (retracted)	586.98	6.02	3533.63
17	Main landing gear (retracted)	2347.93	23.56	55317.21

Table 1.8 – Airplane C.G. position variants

No.	Variants of the loading	Mass, kg	Moment of the mass, kg*m	Center of mass, m	Center of gravity position
1	Take off mass (L.G. extended)	76538.32	1643097.53	21.47	0.26
2	Take off mass (L.G. retracted)	76538.32	1642510.55	21.46	0.26
3	Landing weight (L.G. extended)	57814.20	1226696.10	21.22	0.20
4	Ferry version (without payload, max fuel, LG retracted)	60746.45	1316511.94	21.67	0.31
5	Parking version (without payload, fuel for flight and LG extended)	41868.34	900081.49	21.50	0.27

Conclusion to part 1

Through the preliminary design of the aircraft in the mission, the following conclusions are drawn:

- Preliminary design of the aerodynamic shape of a medium-haul passenger aircraft carrying 150 passengers;
- the internal layout of the aircraft fuselage, cabins and seating arrangements;
- Preliminary computerized wing center of gravity to determine the position of the wing relative to the fuselage.
- Preliminary calculation of the center of gravity of the fuselage and the aircraft as a whole.
- Calculate the geometric parameters and forces of the landing gear, and select the appropriate engine and landing gear tires.
- The T-shaped tail fin layout is adopted to reduce the impact of the air flow on the flat tail and improve the operability.

The two engines are arranged symmetrically under the wing. Mainly because this design has the following advantages:

- The weight of the engine can be used to offset some of the torque generated between the wings and the fuselage;
- Keep the engine away from the fuselage to reduce the impact of malfunction and noise on the fuselage;

According to the calculation results, the Pratt & Whitney JT8D-9 engine was selected as the engine of the aircraft, mainly because of its high bypass ratio and high thrust. Its usage rate and usage time also reflect its superior performance and security.

PART 2FLEXIBLE CONVEYOR DESIGN

2.1. Analysis of existing flexible conveyor

A conveyor belt system consists of two or more pulleys, with an endless loop of carrying medium – the conveyor belt – that rotates around them creating a pull effect for the goods it's carrying.They are popular in the commodity handling and packaging industry due to their ability to accommodate the transportation of various shapes and materials, as well as their efficiency and convenience.

For the baggage handling of civil aircraft, flexible conveyor has better function than traditional belt loader. There are two main types of flexible conveyor, namely power conveyor and gravity conveyor. In the case of aircraft baggage handling, it was decided to use a power roller conveyor to save more vertical space and provide adequate control. At the same time, the Powered Roller Conveyors are 24V conveyors for precise and efficient transportation of containers, totes or boxes. Ideal for zero-pressure accumulation, each zone can be controlled separately. The control units are pre-installed inside the extrusion, covered and ready to use (plug-and-play).

Flexible conveyor is a combination of three-dimensional conveying system, using aluminum alloy or stainless steel frame, plastic steel or industrial plastic conveyor chain. The conveyor chain makes use of the carefully designed stagger structure and hinge fit between the two chain joints, so that it can carry out maximum bending in space. Due to the modular design and mass production of the conveyor chain, rapid installation, length, bending Angle and other parameters can be changed at any time. Because of the sliding movement of the conveyor chain in the aluminum alloy profile, it has the characteristics of dexterous, light, beautiful, compact, quiet and pollution-free. After the design of the transfer structure also makes the conveyor has the advantages of small turning radius and strong climbing ability.(as shown in the figure 2.1) .

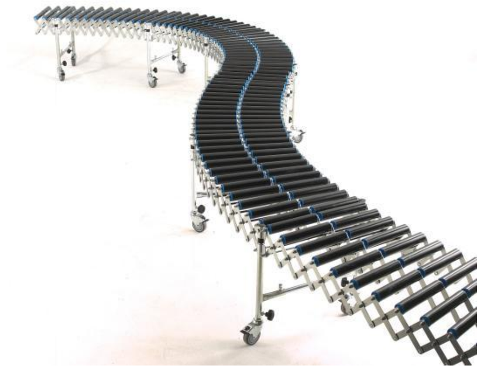

Figure 2.1 – Typical conveyor system

2.2 Requirements to the designed machine

By analyzing the baggage transmission system currently used by civil airliners, I think it is very necessary to design a new type of flexible conveyor according to the transmission working method and the shortcomings of the transmission method.

The first problem is that in traditional handling systems, baggage handling takes a lot of time, which will consume high labor costs and time costs. Secondly, the reliability and life of the existing loading and unloading system are not ideal, so it is necessary to improve the reliability and life by improving materials and maintenance methods. Third, traditional transportation systems such as ball pads and roller pads are heavy and increase fuel consumption in flight. Fourth, workers need to bend down to work in the cargo hold, which will cause harm to workers for a long time.

Accroding to these considerations, following functions should be achieved:

1. Faster transfer speed. Improve the efficiency of luggage transportation.
2. Reduce fuel consumption. Reduce unnecessary weight in aircraft baggage transport systems.
3. Reduce damage to other components. Reduce wear and tear on floors and luggage.
4. Optimize working conditions. Reduce the physical exertion of the staff and reduce the harm to the body.

Therefore, the equipment designed in the second part, the flexible conveying system should achieve the following tasks:

- At the same time bear the load of 200 (10 × 20) kg.
- The speed can reach 100 r/min.
- Complete start-to-stable operation within 3 seconds.
- Gear motor maintenance rate is low.
- Long term durability.

2.3. Some choice of design of the flexible conveyor.

2.3.1.Selection of output mode.

The power flexible conveyor itself has a driving device, and the roller rotates in an active state, which can strictly control the running state of the items, and transport the items accurately, smoothly and reliably at the specified speed, which is convenient for the automatic control of the conveying process.

Therefore, the output form with a power system should be selected according to the requirements of use.

2.3.2.Choice of transmission mode.

Chain drive: large carrying capacity, good versatility, convenient layout, strong adaptability to the environment, and can work in places with frequent contact with oil, water and high temperature. It is the most commonly used type of power roller conveyor. The chain is easy to wear when working in a dusty environment, and the noise is louder when running at high speed. The arrangement of the chain drive can be either a continuous chain configuration or a roller-to-roller chain drive (Figure 2.3.2-1). The continuous chain in a picture is generally used for light loads, and the roller-to-roller chain drive in b. Generally used for heavy loads or frequent reversing or frequent starting, so choose the roller-to-roller chain drive form.

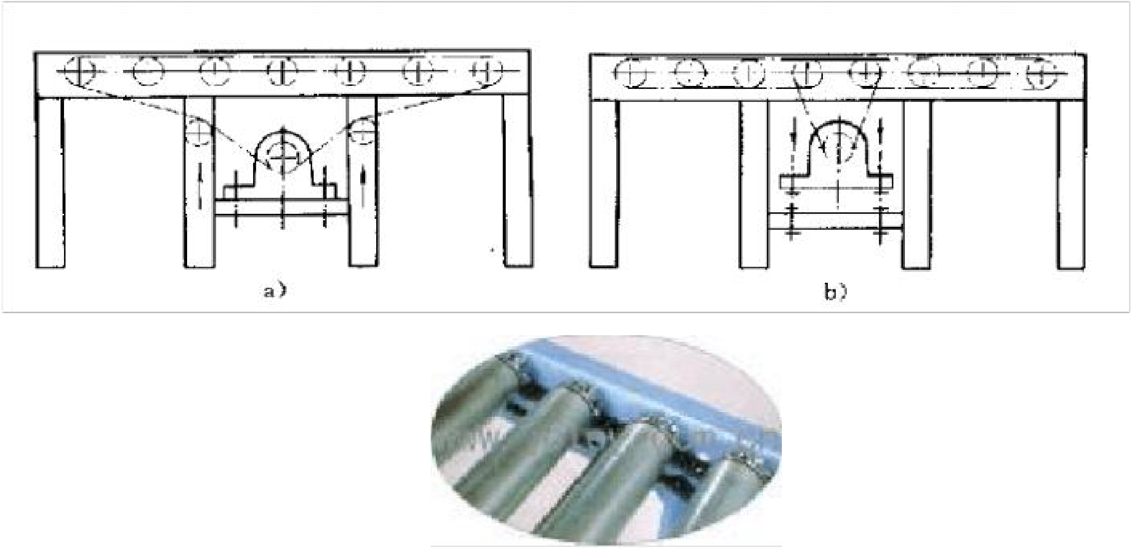

Figure 2.2 – Typical conveyor system

Because the speed needs to be adjusted according to the needs, the transmission mode is selected as the transmission mode of roller-to-roller chain drive.

2.3.3.Choice of roller support.

The rollers of the rotary shaft roller conveyor are connected with the shaft to rotate, and the shaft is supported in the bearing seat fixed at both ends. Rotary rollers are easy to install, adjust and disassemble. It is mostly used in occasions with heavy loads and high running accuracy requirements, and the cost is higher than that of the fixed-axis type.

The quality of the goods is too large, so choose a shaft-type roller.

2.4. Parameter design and verification.

2.4.1.Roller arrangement.

Each suitcase weighs 20kg and is designed to be supported by at least 6 rollers at the same time, so the force on each roller is:

$$F = G/(0.7 * n) = 200/(0.7 * 6) = 47.62N$$

The length of the suitcase is 1000mm, so the distance between the rollers is [take the non-standard value]:

$$l = 1000/7 \approx 142.86mm$$

The length of the work surface is 1500mm, so each work surface is arranged with 10 rollers, and the distance between the first roller and the last roller is 35.7mm from the work surface;

The width of the trunk is 600mm, so the distance between the two supports of the roller is set to 700mm.

2.4.2.Roller size and force analysis.

According to the requirements for luggage size in international airworthiness regulations, the length, width and height of luggage should correspond to 1000mm×600mm×400mm. Based on this, the width of the load is 600mm.

The length of the rollers depends on the load wide and the constant width desire.

$$L = W + \Delta B = 600 + 100 = 700\ (mm);$$

where:

W - width of the load;

ΔB - width desire (100-200 mm).

The supporting force at both ends of the roller is:

$$\mathrm{F} = 47.62/2 = 23.81\mathrm{N}$$

The force of the roller is shown in Figure 2.3:

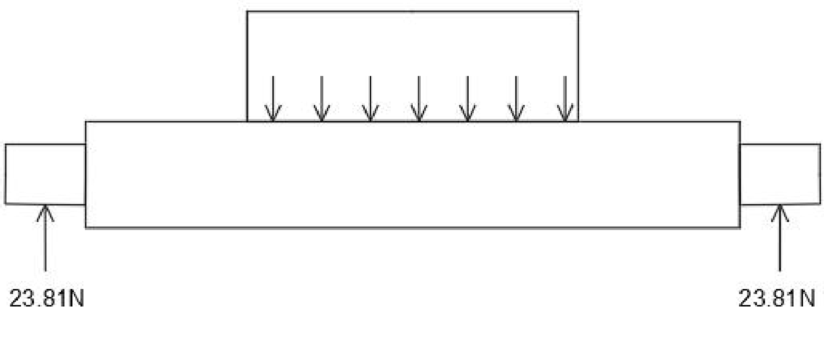

Figure 2.3 The force of the roller

The bending moment of the roller is shown in Figure 2.4:

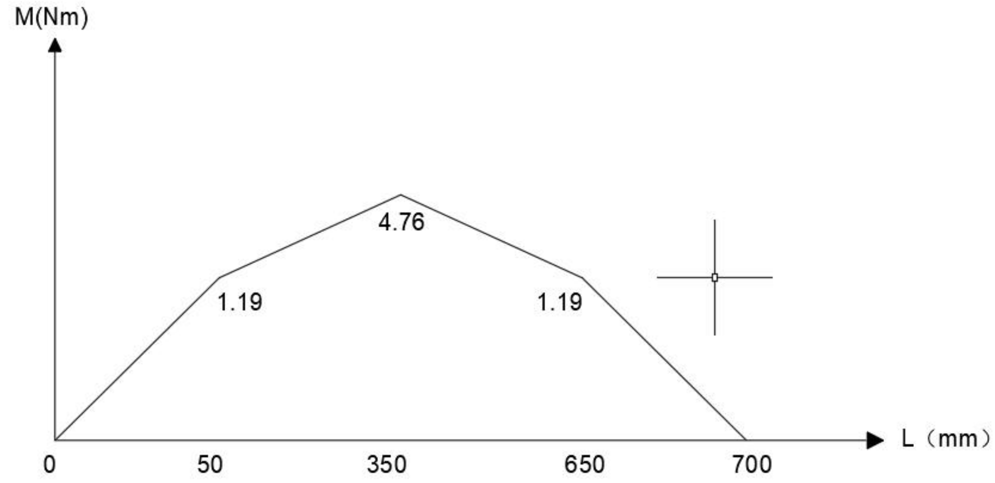

Figure 2.4 The bending moment of the roller

The torques experienced by the rollers over the full length X are shown in Figure 2.5:

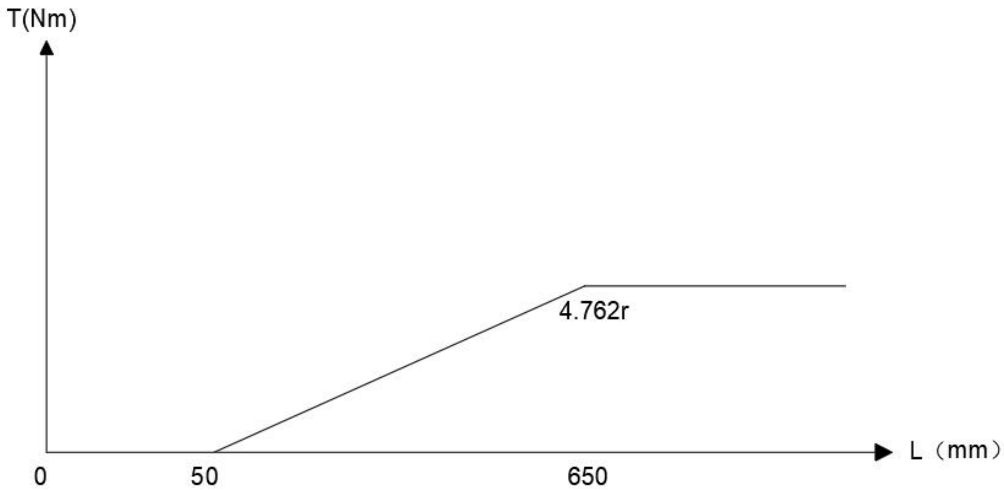

Figure 2.5 torques experienced by the rollers [r is the radius of the axis]

According to the fourth strength theory:

$$\delta_r = \sqrt{\delta_2 + 3\tau_2} \leq [\delta]$$

$$\delta = \frac{M}{W} = 4.76 \div \frac{\pi d^3}{32}$$

$$\tau_{max} = \frac{T}{W_p} = 4.762r \div \frac{\pi d^3}{16}$$

δ is the bending tensile stress;

τ is the torsional shear stress;

$[\delta]$ is the allowable stress, the material is Aluminum Wrought Alloy 2014-T6, so the ultimate shear stress $\tau = 184MPa$. According to the safety consideration, we take the allowable shear stress $[\tau] = 160MPa$.

M is the maximum bending moment of the shaft;

W is the flexural section coefficient;

T is the maximum torque on the shaft;

W_p is the torsional section coefficient;

r is the radius of the dangerous section of the shaft;

d is the diameter of the dangerous section of the shaft;

Therefore, it can be calculated that the diameter of the shaft can be rounded to 44.7 mm;

2.4.3. Bearing selection.

The force analysis of the roller rotation process: the roller is mainly subjected to radial force during the rotation process.

At the same time, according to the previous calculation, the length of the roller is 700 mm, the outer diameter of the roller is 60 mm, and the luggage will be supported by at least three rollers.

So we can calculate the radial force (F_r) of the each bearing and ignore the axial force (F_a).

$$F_r = \frac{G_1}{6} = \frac{470}{6} = 78\ (N);$$

$$\mathrm{F_a} = 0\ (\mathrm{N}).$$

Dynamic load can be calculated by formula:

$$\mathrm{P = X \cdot F_r + Y \cdot F_a = 1 \times 78 + 0 \times 0 = 78\ (N)},$$

where:

F_r - the radial force of the bearing;

F_a - the axial force of the bearing;

X - radial load factor;

Y - axial load factor.

From following table 2.1, we can get the bearing radial load factor is 1 and axial load factor is 0.

Bearing types	Relative axial load		Single row bearing			
			$F_a/F_r \leq e$		$F_a/F_r > e$	
	F_a/C_{or}	F_a/zD_w^2	X	Y	X	Y
Deep groove ball bearing	0.014	0.172	1	0	0.56	2.30
	0.028	0.345				1.99
	0.056	0.689				1.71
	0.084	1.03				1.55
	0.11	1.38				1.45
	0.17	2.07				1.31
	0.28	3.45				1.15
	0.42	5.17				1.04
	0.56	6.89				1.00

Table 2.1 - Load factors of the single row bearings

The rotating speed of the bearing:

$$n_m \approx n = 100\ (\frac{r}{min});$$

The next is that the required axial basic dynamic load rating calculation:

$$C_r = \frac{f_p \cdot p}{f_t}(\frac{60n_m}{10^6}L_h)^{1/\epsilon} = \frac{1.0 \times 78}{1.0} \times (\frac{60 \times 100}{10^6} \times 50000)^{\frac{3}{10}} = 431.7(N),$$

where:

n_m - the rotating speed of the bearing;

P - the dynamic load;

f_p - load factor (take it as 1.0);

f_t - temperature coefficient (take it as 1.0);

L_h - bearing life expectancy (from table 2.2);

ε - life factor (for ball bearing is 10/3).

Working condition	L_h/h, hours
Infrequently used instruments and equipment	500
Short-term or intermittent used, no serious consequences will be caused when interrupted	4000~8000
Intermittent used, interruption will cause serious consequences	8000~12000
Machinery that works 8 hours a day	12000~20000
24-hour continuous working machinery	40000~60000

Table 2.2 - Reference value of the expected life of the bearing

From the machanical design manual: The 61802 bearing $C_r = 2.1kN \geq 0.432kN$; the inner diameter of the bearing is 15mm and the outer diameter is 24mm. Thichness of the bearing is 5mm.

2.4.4. Bearing check

From the machanical design manual, we can get the basic dynamic load rating of bearing 61802 is 2.1 kN. So:

$$L_h = \frac{10^6}{60n_m}\left(\frac{f_t C_r}{f_p P}\right)^{\epsilon} = \frac{10^6}{60 \times 100}\left(\frac{1.0 \times 2100}{1.0 \times 78}\right)^{\frac{10}{3}} = 9641930(h) > 50000(h).$$

The selected bearing life meets the requirements.

2.4.5. General dimension

The flexible conveyor can adapt to various working environments by rolling and bending the conveyor part to meet different needs. In order to achieve this function, the connection between the drum and the drum is very important.

Firgure 2.6 - General view of the conveyor

The flexible conveyor should be able to achieve a 90-degree turn. So that, we need to calculate the diastance between the rollers:

$$d_r \geq \frac{\frac{\pi}{2}L+(\mathrm{n}-1)d}{n-1} = \frac{\frac{\pi}{2}\times 700+(31-1)\times 50}{31-1} = 86.65(mm)$$

So, in order to simplify the calculation, the diastance between the rollers will be taken as:

$$d_r = 87\ (mm);$$

where: d - the distance between the roller and roller;

b - the width of the connecting piece;

L - the length of the roller;

n - the number of the rollers at turning.

The distance between the two rollers is set to 10mm when the equipment is in normal and non-operational working condition. Therefore, the number of rollers (z) can be determined by dividing the length of the conveyor by the distance between the rollers:

$$z = \frac{L}{d+0.01} = \frac{10}{0.05+0.01} = 166.$$

According to that, we can calculate length of the roller after entension by formula:

$$L_{ex} = d(z-1) = 87 \times (166-1) = 14.4(m);$$

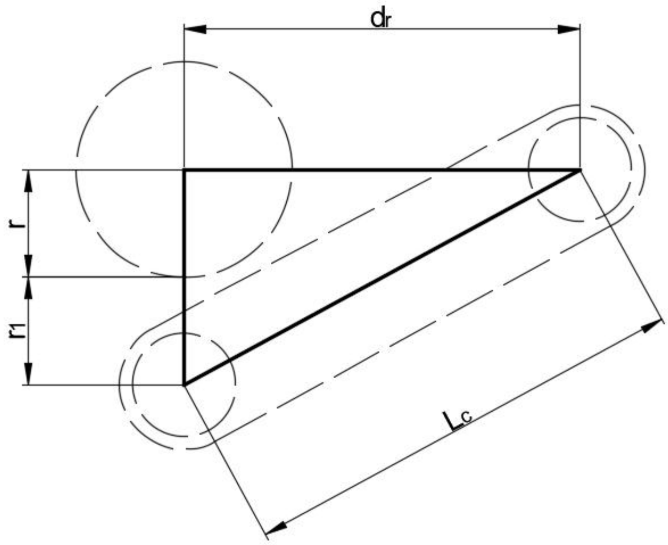

Figure 2.7 - Length of connecting piece calculation

From the figure 2.4.5.2, we can get that the length of connecting piece can be calculate by $L_c = \sqrt{(d_r)^2 + (r + r_1)^2}$.

$$d_r = 87\ (mm);$$

$$r + r_1 = 25 + 25 = 50\ (mm);$$

where: d_r - the distance between the roller and roller;

r - the radius of the roller;

r_1 - the distance between the roller and connecting pieces.

So,

$$L_c = \sqrt{(d_r)^2 + (r + r_1)^2} = \sqrt{87^2 + 50^2} = 100(mm);$$

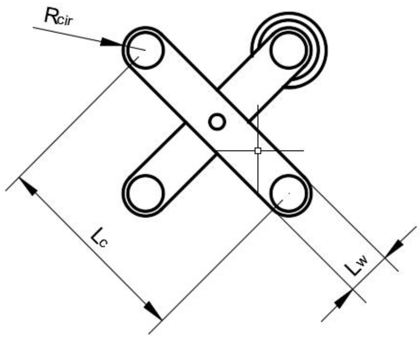

Figure 2.8 - Dimension of the connecting piece

The R_{cir} and L_c are taken as 15mm and 150mm. So that, the length of connecting piece is:

$$L = 2R_{cir} + L_c = 2 \times 15 + 100 = 130\ (mm).$$

Width of connecting piece(L_w) should bigger than the outer diameter of the bearing. So we take it as 30mm. And we take the thickness as 5mm

2.5 Selection of motor and inverter.

2.5.1Calculation of motor power.

According to Ref., the power N of the motor is calculated as follows:

Roller-to-roller chain drive conveyor, chain-to-roller traction P_n:

$$P_n = fWQ\frac{D_r}{D_s}$$

f is the friction coefficient between the luggage case and the roller, and its value is selected as 0.05 according to Table 2.3:

Total load on each roll (including roll weight) N	The surface of the item in contact with the roller		
	smooth metal	wood	nylon
0~110	0.04	0.045	0.05
111~450	0.03	0.035	0.05
451~900	0.025	0.03	0.045
>900	0.02	0.025	0.05

Table 2.3

W is the gravity driven by each power roller, the unit is N;

Q is the coefficient determined by the actual number of driving rollers and the loss coefficient of the roller chain;

D_r is the diameter of the roller;

D_s is the pitch diameter of the sprocket, which is 138mm;

$$W = R_d + A \times R_i + (A + 1)W_r + W_e$$

R_d is the weight of a single drive roller (including sprockets but not shafts);

R_i is the weight of a single driven roller (excluding the shaft);

A is the number of driven rollers on the raceway;

W_r bears the weight of the goods for each roller;

W_e is the weight of a single chain;

$$Q = [(1 + i)n - 1] \div i$$

n is the actual number of rollers;

i is the loss coefficient of the roller chain;

So it is calculated:

$$W \approx 150\ N$$

$$Q \approx 10.9$$

$$P_n = \frac{0.05 \times 150 \times 10.9 \times 0.07}{0.138} = 41.47$$

Motor power N:

$$N = \frac{KP_nV}{1000\eta^2}$$

K is the motor margin coefficient, K =1.15~1.3;

P_n is the traction force of the chain;

V is the speed of the chain;

C is the total transmission efficiency, $\eta = \eta_1 * C_2$, η_1 is the meshing efficiency of the chain and the sprocket, η_1=0.7~0.8, C_2 is the power to increase the acceleration resistance and other resistances, η_2=0.8;

So the power of the motor is equal to:

$$N = \frac{1.2 \times 41.47 \times 0.986}{1000 \times 0.8 \times 0.8} = 0.077kW$$

According to Reference2, the motor is rated at N_J:

$$N_J = \frac{N}{\eta}$$

$$N = N_1 + N_2$$

$$N_1 = (W_1 + W_2)\omega$$

$$W_1 = 9.8(G + Zq)\mu d/2$$

$$W_2 = 9.8G \times k \div 100$$

$$N_2 = GV^2/t_s$$

η is the total mechanical efficiency, choose its value as 0.5;

N1 is the power required to restrain the friction of the roller to do work;

The instantaneous maximum power required by N_2 to restrain the inertial resistance of the mass of the item;

W_1 is the bearing resistance torque at the roller journal;

W_2 is the resistance moment of the object moving along the roller;

Z is the number of rollers, the value is 10;

q is the mass of each roller;

μ is the coefficient of rolling friction, and the value is selected as 0.015 according to the table below:

working conditions	features of working conditions	plain bearing	rolling bearing
good	clean and dry without abrasive dust	0.1~0.15	0.01~0.015
medium	Normal temperature with a small amount of abrasive dust	0.15~0.20	0.01~0.02
bad	Lots of abrasive dust	0.20~0.25	——

Table 2.4

d is the diameter of the joint surface of the plain bearing; for rollers using rolling bearings, the diameter of the roll "journal" d is the nominal diameter where the rolling bearing is mounted between the diameters of the intermediate rolling surfaces of the rolling bearing

k is the coefficient of rolling friction between the article and the roller, taken as 0.05cm.

t_s is the starting time of the motor, because the power is not very large, so choose 1 s;

$$N_J = \frac{N}{\eta} = 0.096\text{kW}$$

According to Reference 3, the power N of the motor:

$$\text{N} = \text{V} * \text{W} * \text{u}/(\text{K} * 0.6) = 1.7\text{HP} = 1.29\text{kW}$$

Based on the results of the above three calculation methods, the rated power of the motor is selected as 1.5 kW;

2.5.2 Calculation of motor rated speed.

The motor and the roller sprocket pass through the chain, the transmission ratio is set to 1:1, the maximum speed of the roller is about 136 r/min,

Therefore, the maximum speed of the motor should be greater than 136 r/min, and the frequency control is selected as the speed control.

2.5.3 Look-up table selection of motor.

The selected motor should be able to provide 1.5kW of power, and the maximum speed is about 136 r/min. According to the above conditions, select the R57-4 type reducer, the output speed is 138 r/min model, with frequency conversion device.

2.5.4 Selection of Inverter.

According to the earring power of the reducer is 1.5kW, the rated current is 3.7A, so choose TL80B series inverter

Conclusion to part 2

In the design of the flexible conveyor in the second part of the thesis, the first consideration is the overall size parameters of the rollers, the bearing parameters, and the selection and parameter selection of the motor.

At the same time, in the careful selection of the roller material, the influence of the material of the luggage on the frictional resistance is considered.

In order to maximize the operating life of the conveying mechanism, in the calculation of material strength and load bearing, the rated requirements should be met as much as possible.

While meeting all design requirements, the intended functionality presented in the design should also be met.

Finally, in the calculation and selection of the motor, based on safety and practicability, a 1.5kW motor was selected to ensure smooth transportation.

GENERAL CONCLUSION

Preliminary designs for the aircraft and flexible conveyors were made in this mission.

In the first part, through the analysis of the current passenger aircraft in the aviation market, the Boeing 727 is used as the prototype to design a medium-haul civil aircraft with a passenger capacity of 150 people. At the same time, the shape and parameters of each part of the aircraft wing (aileron, flap, area, etc.) are designed.

For the wing layout, a low-position wing design with a swept angle is used. In order to achieve good aerodynamic performance of the aircraft wing, the flap type adopts slotted flaps.

The cabin layout inside the fuselage is divided into economy class and business class. The width of the corridor and the arrangement and spacing of the seats are selected by calculation.

In the design of the center of gravity and landing gear of the aircraft, the most classic front three-point landing gear is used to ensure safe take-off and landing. At the same time, the center of gravity under various conditions (full load take-off, landing, etc.) is also carefully calculated.

In the second part of the parameter design of the flexible conveyor, the overall size of the conveying roller, the strength of the bearing, the size of the connection and the power of the motor are mainly considered.

In order to maximize the service life of the conveying mechanism, when calculating the material strength and bearing capacity, the rated requirements should be met as much as possible.

While meeting all design requirements, the intended functionality presented in the design should also be met.

Finally, in the calculation and selection of the motor, based on safety and practicality, a 1.5kW motor was selected to ensure smooth transportation.

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Appendix A

INITIAL DATA AND SELECTED PARAMETERS:

Passenger Number	150
Flight Crew Number	2
Flight Attendant or Load Master Number	4
Mass of Operational Items	1470.29 kg
Payload Mass	15675.00kg
Cruising Speed	840.0 km/h
Cruising Mach Number	0.78
Design Altitude	10.50 km
Flight Range with Maximum Payload	5000 km
Runway Length for the Base Aerodrome	2.95 km
Engine Number	2
Thrust-to-weight Ratio in N/kg	2.90
Pressure Ratio	31.00
Accepted Bypass Ratio	5.50
Optimal Bypass Ratio	5.50
Fuel-to-weight Ratio	0.22
Aspect Ratio	9.50
Taper Ratio	4.20
Mean Thickness Ratio	0.12
Wing Sweepback at Quarter of Chord	29.0°
High-lift Device Coefficient	1.050
Relative Area of Wing Extensions	0
Wing Airfoil Type	supercritical
Winglets	no
Spoilers	yes
Fuselage Diameter	4.20m
Fineness Ratio of the fuselage	9.60
Horizontal Tail Sweep Angle	35.0°
Vertical Tail Sweep Angle	40.0°

CALCULATION RESULTS:

Optimal Lift Coefficient in the Design Cruising Flight Point	Cy=0.46
Induce Drag Coefficient	Cx = 0.0091

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

Cruising Mach Number	0.78
Wave Drag Mach Number	0.80
Calculated Parameter D_m	0.012

Wing Loading in kPa (for Gross Wing Area):

At Takeoff	5.74
At Middle of Cruising Flight	4.89
At the Beginning of Cruising Flight	5.54

Drag Coefficient of the Fuselage and Nacelles	0.012
Drag Coefficient of the Wing and Tail Unit	0.0091

Drag Coefficient of the Airplane:

At the Beginning of Cruising Flight	0.033
At Middle of Cruising Flight	0.031
Mean Lift Coefficient for the Ceiling Flight	0.463
Mean Lift-to-drag Ratio	14.79
Landing Lift Coefficient	1.596
Landing Lift Coefficient (at Stall Speed)	2.394
Takeoff Lift Coefficient (at Stall Speed)	1.975
Lift-off Lift Coefficient	1.442
Thrust-to-weight Ratio at the Beginning of Cruising Flight	0.620
Start Thrust-to-weight Ratio for Cruising Flight	2.473
Start Thrust-to-weight Ratio for Safe Takeoff	2.928
Design Thrust-to-weight Ratio Ro	3.075
Ratio $D_r = R_{cruise} / R_{takeoff}$ Dr	0.845

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

Takeoff	35.62
Cruising Flight	58.25
Mean cruising for Given Range	61.75

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.038
Block Fuel	0.248

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.1095
Horizontal Tail	0.0099
Vertical Tail	0.0098
Landing Gear	0.0389
Power Plant	0.0940
Fuselage	0.0906
Equipment and Flight Control	0.1308
Additional Equipment	0.0037
Operational Items	0.0195
Fuel	0.2857
Payload	0.2077

DATA OF TAKEOFF:

Airplane Takeoff Weight	M =75467kg
Takeoff Thrust Required of the Engine	116.01kN

FRACTION OF SOME PART OF AIRCRAFT:

Air Conditioning and Anti-icing Equipment Weight Fraction	0.0224
Passenger Equipment Weight Fraction (or Cargo Cabin Equipment)	0.0161
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.0090
Furnishing Equipment Weight Fraction	0.0100
Flight Control Weight Fraction	0.0063
Hydraulic System Weight Fraction	0.0171
Electrical Equipment Weight Fraction	0.0325
Radar Weight Fraction	0.0032
Navigation Equipment Weight Fraction	0.0047
Radio Communication Equipment Weight Fraction	0.0024
Instrument Equipment Weight Fraction	0.0055
Fuel System Weight Fraction	0.0084

ADDITIONAL EQUIPMENT:

Equipment for Container Loading	0.0000
No typical Equipment Weight Fraction(Build-in Test Equipment for Fault Diagnosis Additional Equipment of Passenger Cabin)	0.0037

TAKEOFF DISTANCE PARAMETERS:

Airplane Lift-off Speed	287.22km/h
Acceleration during Takeoff Run	2.39m/s^2
Airplane Takeoff Run Distance	1330m
Airborne Takeoff Distance	578m
Takeoff Distance	1909m

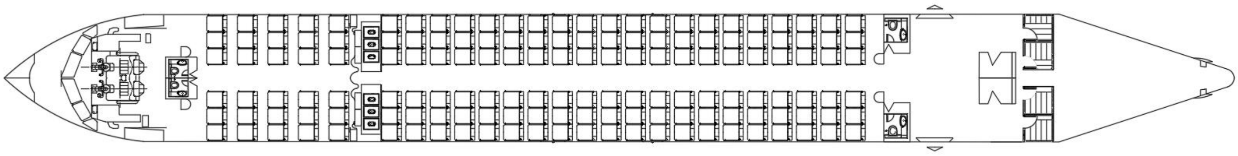
CONTINUED TAKEOFF DISTANCE PARAMETERS:

Decision Speed	272.86 km/h
Mean Acceleration for Continued Takeoff on Wet Runway	0.29m/s^2
Takeoff Run Distance for Continued Takeoff on Wet Runway	2237.77m
Continued Takeoff Distance	2816.15m
Runway Length Required for Rejected Takeoff	2917.05m

LANDING DISTANCE PARAMETERS:

Airplane Maximum Landing Weight	59985kg
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight	20.8min
Descent Distance	48.61km
Approach Speed	261.72km
Mean Vertical Speed	2.09m/s
Airborne Landing Distance	522m
Landing Speed	246.72km/h
Landing run distance	818m
Landing Distance	1339m
Runway Length Required for Regular Aerodrome	2237m
Runway Length Required for Alternate Aerodrome	1902m

Appendix B



Aircraft cabin layout top view