МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Кафедра конструкції літальних апаратів

«ДОПУСТИТИ ДО ЗАХИСТУ»
Завідувач кафедри
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(підпис)
« _____»___________________ 2021 р.

ДИПЛОМНИЙ ПРОЕКТ

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬО-КВАЛІФІКАЦІЙНОГО РІВНЯ

«БАКАЛАВР»

Тема: « Попередній проект пасажирського літака середньої дальності місткістю 106 пасажирів »

Виконала: ____________ Хаохао Ван

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

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Київ 2021

MINISRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY
Aircraft Design Department

AGREED
Professor, Dr. of Sc.
_________S.R. Ignatovych
«___» _______ 2021

DIPLOMA WORK

(EXPLANATORY NOTE)
OF EDUCATIONAL DEGREE

«BACHELOR»

Theme: « Preliminary design of the mid-range passenger plane with a capacity of 106 passengers »

Performed by: __________ Wang Haohao

Supervisor: Dr. of Science, Professor __________ M. V. Karuskevich

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

Kyiv 2021
NATIOONAL 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
«____ » ___________ 2021

TASK
for bachelor diploma work
YOUR NAME AND SURNAME

1. Theme: «**Preliminary design of the mid-range passanger plane with 106 passanger capacity**»

   Confirmed by Rector's order from …….. year № …..
2. Period of work execution ___2021/2/3___ to ___2021/5/25___
3. Work initial data:
   - Maximum payload – n = 106 passengers;
   - Flight range with maximum payload – $L_{пол}$= 4537 Km;
   - Cruise speed – V_{cr} = 829 Km/h at operating altitude H_{op}= 12 Km;
   - Landing speed – V_{land} = 240.0 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 winch (A1×2).

6. Calendar Plan

№ п/п	Task	Execution period	Signature
1	Task receiving, processing of statistical data	15.05.21	
2	Aircraft take-off mass determination	19.05.21	
3	Aircraft layout	19.05.21	
4	Aircraft centering determination	25.05.21	
5	Graphical design of the parts	25.05.21	
6	Preliminary defence		
7	Completion of the explanation note		

7. Task date: «___» ___________ 2021

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

Task is given for: _________________ Wang Haohao
(signature)

ABSTRACT

Explanatory note to the diploma work «preliminary design of the mid-range passenger plane with 106 passenger capacity» contains:

63 pages, 5 figures, 15 tables, 13 references and 4 drawings

Object of the design is development of the mid-range aircraft with 106 passenger capacity.

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

The methods of design are to analyze of the prototypes and select of the most advanced technical decisions to calculate the geometry for main parts of the fuselage, such as wing geometry calculation, fuselage layout and landing gear design. Besides center of graity calculation is another significant portion in the design.

The diploma work contains drawings of the mid-range aircraft with 106 passengers, calculations and drawings of the aircraft layout, flexible conveyor concept, calculations and drawing.

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

CONTENT

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Performed	Wang Haohao			CONTENT	Letter	куш	Аркушів
Supervisor	Karuskevich						52
Adviser					FLA 402 6.051101		
Stand.contr.	Khizhnyak S.						
Head of dep.	Ignatovych S.						

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 organziation
FAR	Federal aviation regulation
CS	Certification specification
CCAR	Chinese civil aviation regulation
FC	Flexible conveyor
C.M	The center of the mass

List of drawings

№ п/п	Name of drawings	Format	Number of sheets
1	Cargo SRA (general view)	A1	1
2	Cargo SRA (layout)	A1	1
3	Flexible conveyor (assembly drawing)	A1	1
4	Detailed view of the flexible conveyor	A1	1

Introduction

In 2020, the COVID-19 pandemic delivered the large crisis to air travel and aviation industry. According to the data from IATA and ICAO, the international decline of the RPKs peaked in April, it was down 94% from the year before. Even now, on one can predicts how long will the COVID-19 last and how long the aviation industry will suffer the challenge. But one thing is for sure, modern society cannot exist without air transport.

From the perspective of the development of the trend in past 20 year(excluding the special case of COVID-19), the global regional passenger plane market has a certain scale and is still in the stage of continous growth. The anaylsis about distribution of regional passenger plane market shows that the Eurpoe and United States is in the domination of market with relativly mature operation method. At the same time, Aisa is in the development stage in regional aviation. International regional pessenger market still has a lagrge potential to develop. But the first thing that needs to be considered is what the current social travel neefits.

The aim of the work is designing a mid-range plane with a capacity of 106 passengers. And the objectives of the work are including aircraft preliminary design stages: wing and fuselage geometry calculation, primary control surface calculation, center of gravity calculation and designing. The special part deals with conceptual and preliminary design of flexible conveyor.

The aircraft uses a low-wing structure. A typical tail unit (T type) has an adjustable vertical stabilizer mounted on the tail and two GE CF34-10E turbofan bypass engines, with a thrust of 20360 Ibf (90.6kN) installed under the wings. Among them, the engine's 3LP and 9HP compressors can provide large compression ratios. As for the rudder and elevator, the presence of aerodynamic balance device helps to control the attitude of the aircraft.

The cargo hatch for loading and unloading passenger luggage is located in the lower part of the fuselage.

The project reflects that people are more inclined to choose regional airliners when traveling mid or long distances. Its comfort, economy and most importantly, timeliness are irreolaceable. Also, such aircraft must be reliable, which in poor take-off and landing conditions is an extremely difficult task.

We take some national and international starndrads, airworthiness laws, rules, recommendations into account, including FAR-25, CS-25, ICAO civil aviation law and CCAR-25. The following are some of the requiements for civil aircraft: low fuel consumption; high equipment redundancy; excellent climb performance and the largest possible coargo storage volumn.

A special part of this work is about the development of a conveyor belt. The highlight of this design is its scalability and flexibility.

PART 1
PRELIMINARY DESIGN OF THE PLANE

1.1. Analysis of similar planes

In the preliminary design stage, it is very important to refer to and analyze past successful cases. The parameters of aerodynamics, cabin, structural strength and fuel consumption will affect the economy of the aircraft.

At the same time, the analysis of basic parameters such as the overall size of the aircraft, the type of wings and high lift device, and other basic parameters is also an important step in the preliminary design.

Finally, we decided to chose Emberar ERJ-190, Airbus A318, and Bombardier CRJ-900 aircraft with similar parameters as the prototype.

It is very wise to use the good level of the aircraft as a guide to select the required design parameters of the aircraft, that is, to use the main characteristics of the aircraft (prototype aircraft). For example, Embraer's experience in the regional aviation market is a set of examples for "analysis and synthesis." Since the design bureau has been focusing on the design of medium-range passenger aircraft for many years, it finally succeeded in occupying a place in the regional aircraft market.

Bombardier's area (CRJ900) company and Airbus A318 are also considered as successful cases in this paper.

Embraer E-190, Bombardier CRJ-900 and Airbus A318 aircraft will be used as prototypes for this design. In the following parameter calculations, take their specific parameters as a reference.

First, compare the specific information of the three prototypes. And the statistic data of prototypes are presented in table 1.1.

Table 1.1 – Statistic data of prototypes

PARAMETERS	PROTOTYPE		
	E-190	CRJ-900	A318
The purpose of airplane	passenger	passenger	passenger
Crew/flight attend (Persons)	2/3	2/3	2/2
Maximum take-off weight, m_{tow}, kg	51800	38000	68000
Passenger's seat	100	88	117
The height of the flight $V_{w.\ ек.}$, m	12000	12479	12500
Most pay-load, $m_{c.max}$, kg	13063	10247	13300
Range $m_{к.max}$, km	4537	2876	5740
Take off distance $L_{зл.д.}$, m	2100	1939	1780
Landing distance, m	1244	1632	1230
Landing speed, km / h	240	240	240
Cruising speed, Vkm/h	829	829	829
Number and type of engines	2×GE CF34-10E	2×GE CF34-8C5	2×PW6000
Thrust of engines, kN	2×90.6	2×64.5	2×85
Overall pressure ratio	29	28.5	28.2
Fuel consumption of cruising, kg/hour	1970	2100	1859
Mass of fuel, kg	12971	8822	19368
Landing gear scheme	TLG	TLG	TLG
The form of the cross-section fuselage	Circular	Circular	Circular
Length of aircraft, m	36.24	36.2	31.44
Height of aircraft, m	10.57	7.5	12.56
Diameter of fuselage, m	2.7	2,7	3.9

Continuation of table 1.1

Extension of the fuselage	9.27	9.5	8.4
Wingspan, m	28.72	24.9	34.1
Aspect ratio	8.91	8.72	9.50
Taper ratio	4	3.75	3.5
Sweepback on 1/4 chord, °	25°	30°	25°

The plan of the aircraft is determined by the relative position, number and shape of the units. The design experience and parameters of similar aircraft will give us great inspiration. And choosing to refer to the existing successful aircraft can improve flight safety and aircraft economy. In our mission: In the preliminary design of medium-range passenger aircraft, some units that have been successfully applied to other aircraft can be adopted and improved.

Therefore, it is reasonable and wise to make some improvements to the main components (wing, tail, power unit, and fuselage) according to the given technical and economic requirements.

Based on the data provided in Table 1.1, a careful study and analysis of the prototype will provides the possibility to achieve the best characteristics for the design of this new aircraft.

The following content remains to be confirmed:

— the relevant parameters of the wing, the selection and application of the types of slits and flaps, the location and type of the engine;

— The position of the center of gravity, the arrangement of the landing gear and the choice of tires.

1.2. New plane description

Our task is to design a mid-range regional aircraft with a specified capacity of 106 passengers.

As a reference prototype, we chose E-190 because it is a relatively successful aircraft in regional aviation. It has good characteristics and low fuel consumption, which can fully meet our travel needs for short- and medium-distance travel.

The designed aircraft should be able to achieve the following functions: carrying 106 passengers, a range of 4000-5000 kilometers, and a cruising speed of not less than 800 kilometers/hour.

The designed plane is a monoplane with a low-wing structure, and its two turbofan engines are installed under the wings, rated at 82.29kN. It is equipped with winglet at the end of the wing, which not only increases the effective chord aspect ratio of the wing but also reduces the induced drag. In addition, it has a tail vertical unit and a horizontal tail with a T-shape. The large horizontal tail make aircraft have porper static stability. The good static stability enables the aircraft automatically returns to its orginal attiyude when it is distributed by the airflow, during the flight. The wing is straight in the root, trapezius closer to the tips has sweepback angle on ¼ chord 27°. The wing is a wing box structure, which consists of upper and lower panels, ribs and spars and stringers.

The designed aircraft have a semi-monocoque fuselage structure. And the fuselage adopts a circular cross-section design to provide maximum space utilization. The fuselage can be divided into three cabins according to functions: passenger cabin, cockpit and cargo compartment. As for passenger cabin, there are divided into ecnomy and business cabins. And two cargo compartments are located underfloor. The cockpit follows the trend of rounded edges, which improves the safety of the crew. The cockpit and passenger cabin are separated by a lockable bulkhead.

And the cabins above the floor of the aircraft can be divided into business class and economy class. Among them, business class is arranged in the form of 1+2, and economy class is arranged in the form of 2+2. As for the cargo bays are located under the floor, one in front of the wing and the other behind the wing. It is mainly used to place passengers' luggages.

1.2.1. Wing

Aircraft equipped with low wing and winglets, has two GE CF34-10E engines, swept-back wing with the high aspect ratio. It can provide wing with high lift-to-drag ratio and improved the fuel economy.

From the structural analysis, the wing consists of ribs, spars, skins and longitudinal beams. It also has high-lift devices: the slot on the leading edge, the flaps on the trailing edge, the ailerons and the spoiler are also stepped above the wing skin. These lifting devices have significantly improved the aircraft's take-off and landing characteristics and maneuverability.

The wing has been divided into three parts by front spar and rear spar. They are torsion box, leading edge and trailing edge. The center part of the wing is torsion box, carrying the primary loading in the wing. It also can be the attachment point for other wing components such as leading adge, trailing edge and wing-tip devices. There is slotted slat and double-slotted flap attcthed to the leading edge and trailing edge respectively.

The wing structure is a torsion box (caisson) type consisting of 2 spars, ribs, skins and longitudinal beams. Due to different types of loads, the thickness of the wing skin varies in different areas. There is an anti-icing device situated on the leading edge of the wing, which heated by air.

The fuel tank compartment is located in the middle of the wing and is sealed by sealant.

Spars of the wing - beam type, consist of the upper and lower caps on the webs, carrying the flight load and the weight of the wing on the ground. The spar is composed of a sheet aluminum spar web, with ‘T’-shaped spar. The caps are riveted to the top and botton of the plate to prevent under the applied load.

The ribs of the wing are beam-type and can be disassembled. It can maintain the shape of the airfoil and transmit local aerodynamic loads.

On each wing there is a double-slotted flap located at the trailing edge.

Each flap consists of a skin, a set of ribs, a spar and two carriages. Flaps are fastened using brackets.

The flaps are high-lift device installed on the trailing edge of the wing, which can reduce the stall speed of the wing under a given weight. Flaps are usually used during take-off and landing to reduce the take-off distance and landing distance, but they must be retracted when not needed to reduce parasite drag. And the flap deflection angle at take-off - 20°, at landing - 60°.

Ailerons are articulated flight control surface, usually placed on the trailing edge of the wing. They are used in pairs to control the roll of the aircraft. When the right aileron deviates upward by 20°, and the left aileron downward by 20°, the aircraft will rotate clockwise.

1.2.2. Tail Unit

The aircraft adopted a classic T-shaped empennage design,including horizontal tail and vertical stabilizers.

The horizontal tail is a small wing at the tail of the fuselage, which is related to the static stability of the aircraft. Its main function is to maintain the pitch balance of the aircraft during flight. When the elevator deflects downward to increase the lift of the tail wing, so that the rear part of the aircraft deflects upwards around the center of gravity, and the front part deflects downward, so that the aircraft enters a dive state; otherwise, the aircraft enters a climb state.

Each elevator has a servo option card for balance compensation.

Vertical empennage includes: fin, trim tab and rudder. The rudder is a movable aerofoil that is used to turn the aircraft nose right and left. Servo tab is mounted on the rudder.

And swept back angle of the horizontal stabilizer is 31°. As for vertical stabilizer, the swept back angle is 42°.

1.2.3. Power Plant

The power plant consists of two turbofan engines (GE CF34-10E) with thrust of 89 KN each and Hamilton Sundstrand APU. The engine is installed in the nacelle in the center of the wing. Each engine is mounted on a truss, which is mounted on the rear spar of the central partof the wing using a frame through reinforced partitions.

For turbofan engine, the following are mounted on the engine: ignition, cowl, induction, as well as fuel system, anti-icing system, oil system, cooling system and electrical system.

Hamilton Sundstrand APU is installed in the tail cone of the aircraft. It provides:

— addtional source of electrical power in the event of the loss of an engine generator;

— source of bleed air for starter assist for an inflight engine relight;

— a 4% saving in aircraft fuel, as the engine will not need to start up until just before take-off.

Each engine is equipped with an air extraction device, and an alternator is also built, which is the mian source of electricity. Its various parameters will be displayed on the cockpit control panel, and then the pilot can adjust and monitor it.

1.2.4. Landing Gear

The designed aircraft is equipped with a retractable front tricycle type two-wheel landing gear. Its main function is to support the aircraft on the ground and allow it to taxi, while bearing the huge load of take-off and landing.

The main landing gear is installed in the engine nacelle and retracted into the special compartment of the wing after takeoff and during flight. On each landing gear, two wheels with shock absorbers, pneumatic devices and disc brakes are installed.

The nose landing gear is mounted on the front of the fuselage and retracts forward into the cabin under the cockpit during flight. On the front support rod, two non-brake wheels with pneumatics are installed on a common rotating shaft.

The power cylinder of the aircraft hydraulic system can realize the pulling out and retracting of the landing gear, unlocking, the braking of the main landing gear and the rotation of the nose landing gear. When the hydraulic system fails, the lock in the retracted position of the landing gear can be manually opened. In this case, the landing gear will extend and be fixed in the release position under the influence of its own weight and airflow.

1.2.5. Flight Control System

The designed aircraft uses a ‘fly-by-wire’ flight control system to replace the conventional physical connection between the pilot and flight control surface with an electrical interface. In addition, control has been enhanced through the hydraulic and electric systems. Simultaniously, the fly-by-wire control and boosted control devices will feedback the feeling of the contorl surface to the pilot through simulated means.

The control system consists of primary and secndary systems. Primary control systems include:

- ailerons;
- rudder;
- elevator.

Secondary control systems include:

- wing flaps and leading edge devices;
- spoilers;
- trim systems.

The aircraft control system has been carefully designed to provide sufficient responsiveness to control input while maintaining a natural feel whether in high or low speed. The movement of three primary control surface will cause the aircraft to rotate around its three axes. Trim system usually consists of a cockpit control device and a small articulated device. And trim tabs are installed on the elevator and there is a servo tab on the rudder.

The pilot's center console on the steering wheel has flap control swithcher, elevator trim tabs, rudder and aileron trim tabs, as well as a rudder and aileron locking knob. The handle that controls the wheels of the rear landing gear is located on the left pilot's console. The autopilot control panel is located on the center panel.

1.3. Substantiation of the new aircraft parameters

1.3.1. Wing geometry calculation

Geometrical characteristics of the wing are relatived to the take off weight m_0 and specific wing load P_0 (wing loading).

Take off weight m_0 has been calculated to be equal to 50101 kg.

Wing loading value P_0 has been accepted on the base of similar planes analysis. So: P_0 =4.75 kPa; m_0=50101 kg.

From this:

Full wing area with extensions is:

$$S_w = \frac{G_0}{P_0} = \frac{m_0 \cdot g}{P_0} = \frac{50101 \times 9.8}{4.75 \times 10^3} = 103.37(m^2).$$

The aspect ratio is an important feature of the wing. Often, the larger the aspect ratio of the wing, the higher the aerodynamic efficiency of the wing.

Some examples of the aspect ratio values are presented in table 1.3.

For proposed plane the value of aspect ratio 8.91 has been selected.

Wing span is:

$$l_w = \sqrt{S_w \cdot \lambda} = \sqrt{103.37 \times 8.91} \approx 30.3(m),$$

where:

λ - aspect ratio.

Root chord is:

$$b_0 = \frac{2S_w \cdot \eta_w}{(1+\eta_w) \cdot l_w} = \frac{2 \times 103.37 \times 4}{(1+4) \cdot 30.3} = 5.46(\mathrm{m}),$$

where:

η_w – taper ratio (calculate as root chord divided by tip chord).

Table 1.2 - Aspect ratio examples

№	Aircraft type	Aspect ratio
1	Hang glider	4-8
2	Glider (sailplane)	20-40
3	Homebuilt	4-7
4	General Aviation	5-9
5	Jet trainer	4-8
6	Low subsonic transport	6-9
7	High subsonic transport	8-12
8	Supersonic fighter	2-4
9	Tactical missile	0.3-1
10	Hypersonic aircraft	1-3

Tip chord is:

$$b_t = \frac{b_o}{\eta_w} = \frac{5.46}{4} = 1.365\ (m);$$

Board chord is:

$$b_{ob} = b_0 \cdot \left(1 - \frac{(\eta_w - 1)\cdot D_f}{\eta_w \cdot l_w}\right) = 5.46 \times \left(1 - \frac{(4-1)\times 3.01}{4\times 30.3}\right) = 5.05(m),$$

Where:

D_f - diameter of fuselage.

The wing taper ratio is also an important geometric parameter of the wing. We set it to 4 based on the following considerations:

1) The plane shape should follow the extra lift distribution of the elliptical shape. This design can avoid the large deviation caused by the distortion required for low cruise resistance;
2) the chord distribution should be such that with the cruise lift distribution, the distribution of lift coefficient is compatible with the section performance. Avoid the appearance of high C_L (lift coefficient) that may cause buffet or drag rise or separation;

3) the chord distribution should produce an additional load distribution which is compatible with the high lift system and desired stalling characteristics;
4) the tip chord should not be too small as Reynolds number effects cause reduced C_L capability;
5) due to the local lift coefficient at the tip area of the wing is higher than the root, reducing the taper ratio too much will cause the wing tip to stall. In addition, it was found that the size of the wingtip vortex increased when the taper ratio increased;

The most significant requirment is to keep the taper ratio belong the range 1.67-5 which has the minimum induce drag coefficient and maximum Oswald effciency factor value. Also, there will be no excessive C_L variation or unacceptable stalling characteristics.

Thickness ratio is also an important parameter in wing design. Some examples of aspect ratio values are provided in Table 1.3.

Table 1.3 - Thickness ratio examples

№	Aircraft type	t/c ratio (%)
1	ERJ 145	11.00
2	CRJ 100	10.83
3	Avro RJ	12.98
4	Boeing 737 classic	12.89
5	DC-9	11.60
6	Fokker 100/70	10.28
7	A320	11.92
8	A310	11.8
9	A300	10.5
10	Boeing 767	11.5

Finally, the thickness and chord values are set at 0.120. The reasons are as follows:

1) greater t/c increases fuel volum and wing stiffness;
2) without a particularly significant impact on the aerodynamic performance of the aerofoil, a relatively large thickness ratio (t/c) will reduce wing weight (thereby permitting larger span, more structural supports, for example);
3) In subsonic flight, the parasitic resistance depends largely on the total area. Therefore, the design of the wing with a small chord length can achieve a high aspect ratio to reduce the parasitic resistance. Such a design naturally has a high thickness ratio;
4) in subsonic flight, the compressibility of the flow is not very important. According to this consideration, the wing can provide good strcutural depth with low profile drag penalty when the thickness ratio beneath the 0.2;

The swept wing has the advantage of providing a higher cruise Mach number. Therefore, the designed aircraft adopts the design of swept wing, and the swept angle on 1/4 chord is 27°. The purpose of the swept back design is to prevent wave drag, so that the aircraft can easily achieve high Mach numbers and have good performance. But the shortcomings of swept wings are also obvious. When the aircraft is at low speed, the airflow will not only flow along the airfoil, but also part of the airflow will move in the spanwise direction of the leading edge of the wing. Based on this, at the tip of the wing, most of the airflow moves along the wing, instead of moving over the wing, so that the wing tip does not generate lift. However, we do not need to worry. Because the leading edge slats and flaps alleviate this problem to a large extent.

For the selection of the wing structure scheme, we only need to determine the main structure of the wing: the connection between the skin and each structure, the number and location of the spars, and the types of ribs and longitudinal beams.

On modern transport aircraft, the most common wing structure is a two spar or three spar design. The wing design with two spars have been selected as appropriate (fig 1.1).

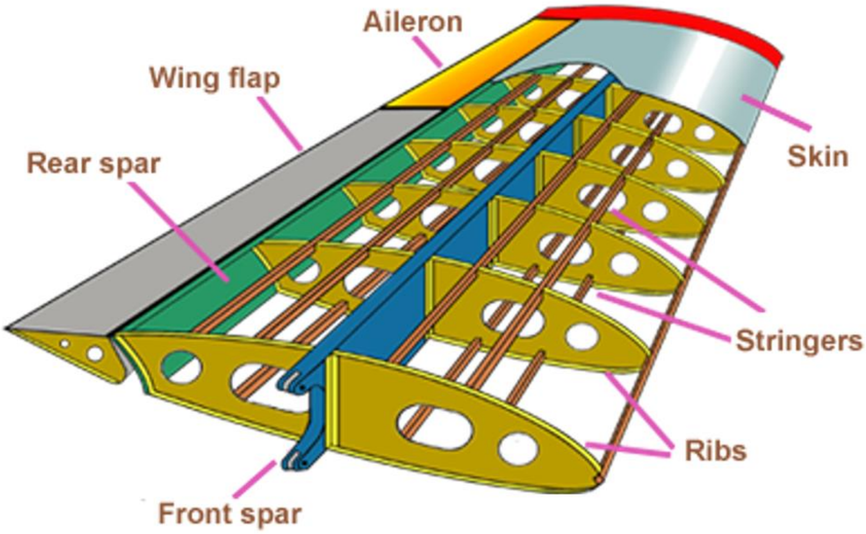

Fig 1.1 - Two spars wing design

Mean aerodynamic chord determined by geometrical method was shown in figure 1.2. Mean aerodynamic chord is equal: b_{MAC}=3.822 m.

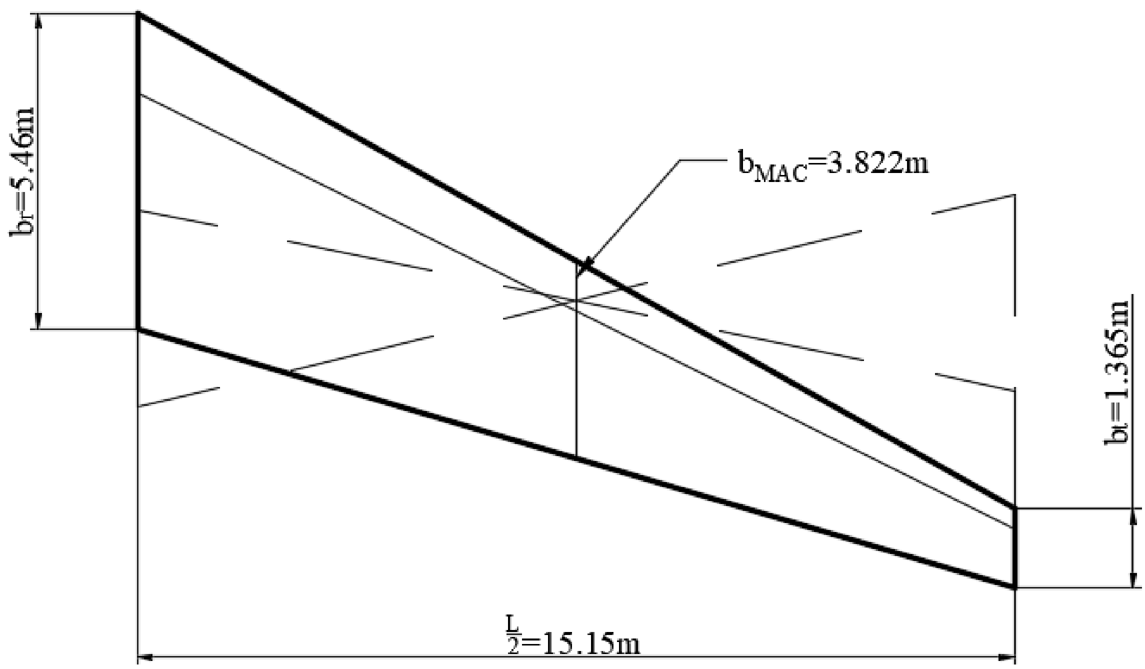

Figure 1.2 - The mean aerodynamic chord of the wing determined by the geometric method

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

The design of ailerons is based on the following parameters, required hinge moment, aileron effectiveness aerodynamic and cost. As a general guidance, the aileron to wing chord ratio is about 22% to 26%, aileron to wing span ratio is about 30% to 40%, and the aileron to wing area ratio is about 5% to 8%.

I have corrected the obtained data according to the current practice. Ailerons geometrical parameters calculation are shown in next consequence;

Ailerons span: $l_{ail} = (0.3 \dots 0.4) \cdot \frac{\mathrm{l_w}}{2} = 0.375 \times \frac{30.3}{2} = 5.6815(\mathrm{m})$;

ailerons chords: $\mathrm{b_{ail}} = (0.22 \dots 0.26) \cdot \mathrm{b_t} = 0.25 \times 1.365 = 0.34125(\mathrm{m})$;

aileron area: $\mathrm{S_{ail}} = (0.05 \dots 0.08) \cdot \frac{\mathrm{S_w}}{2} = 0.065 \times \frac{103.37}{2} = 3.3595(\mathrm{m^2})$.

It is not imperative to increase the l_{ail} and b_{ail} as high as possible. On the contary, keeping them within the recommended values is resonible and convenient. As the value of l_{ail} exceeds the recommended value, the increasing trend of the aileron coefficient slows down, and the span of the high-lift device decrease. With b_{ail} increase, the width of the xenon decreases.

Due to the high speed requirements of airplanes in today's era, the design of modern aircaft tends to decrease relative wing span and ailerons area. In this case, the transversal controlability of the aircraft will deteriroate. Therefore, we adopted a design that uses spoilers and ailerons together to make up for the lack of transversal control of the aircraft. In addition, it is necessary to increase the span and area of the high-lift device to improve the aircraft's take-off and landing characteristics.

Aerodynamic compensation of the aileron.

Axial: $S_{axinail} \leq (0.25 \dots 0.28) \cdot S_{ail} = 0.26 \times 3.3595 = 0.87347(m^2)$;

Inner axial compensation:

$S_{inaxinail} \leq (0.3 \dots 0.31) \cdot S_{ail} = 0.3 \times 3.3595 = 1.00785(m^2)$;

Area of ailerons trim tab:

For two engine airplane: $S_{trim\,tab} = (0.05 \dots 0.06) \cdot S_{ail} = 0.05 \times 3.3595 = 0.167975(m^2)$.

Range of aileron deflection:

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

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

Before doing following calculations, it is necessary to choose the type of airfoil due to the airfoil catalog.

According to the aerofil, we specify the value of lift coefficient $C_{ymax\ bw}$ and determine necessary increase for this coefficient C_{max} for the high-lift devices outlet by the formula:

$$\Delta C_{ymax} = \frac{(C_{ymaxl})}{(C_{ymax\ bw})} = \frac{2.305}{1.934} = 1.1937;$$

C_{ymaxl} - landing lift coefficient (at stall speed);

$C_{ymax\ bw}$ - take off lift coefficient (at stall speed).

where C_{ymaxl} – necessary coefficient of the lifting force in the landing configuration of the wing by the aircraft landing insuring (it is determined during the choice is the aircraft parameters).

Regarding the choice of the high-lift system, one the one hand, the design of an effective high-lift system is more complicated than a simple and ineffective system, which will lead to higher pruchase and maintenance costs. On the other hand, compared with the overall desigh of a simple high-lift system, a more effective system can achieve a better lift-to-drag ratio by buliding a lighter wing, thereby saving fuel. Usually, only through detailed research can the best compromise be found. Therefore, in the early stage of design, statistics on the selection of aircraft height-enhancing devices at home and abroad and learning from their manufacturing experience are of great significance for us in the choice of articulation schemes and kinematics of high-lift devices.

Table 1.4 - The classic used high-lift devices

Aircraft	Type of slats	Type of flaps
Embraer E-190	Leading edge slat	Double slotted flap
Bombardier CRJ-900	Kruger slat	One slotted flap
Boeing 737-500	Kruger slat	Double slotted flap

Continuation of the table 1.4

Airbus 318	Leading edge slat	One slotted flap
Fokker 70	Leading edge slat	Double slotted flap

It can be seen from Table 1.4 that most of the high-lift devices used in similar aircraft are the leading edge slat and single-slit flap structure. Therefore, we decided to adopt the leading edge slat and one-slotted flap structure.

Next, we need to determine the geometric parameters of the wing lift device.

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

for the one slotted and two slotted flaps, the relative chords are in the range of 0.25-0.3;

for one leading edge slats, the relative chords are in the range of 0.1-0.15.

As for the double-slotted flap structure:

$$b_{fl} = (0.28 \dots 0.3) \cdot b_{i1} = 0.3 \times 2.0 = 0.6(m);$$

where:

b_{fl} – the chord of the flap;

b_{i1} - the chord of the section which the flap starts (near the wing tip).

As for the leading edge slats structure:

$$b_{sl} = (0.1 \dots 0.15) \cdot b_{i2} = 0.1 \times 5.40 = 0.54(m).$$

where:

b_{sl} – the chord of the slat;

b_{i2} - the chord of the section which the slat starts (near the wing root).

1.3.2. Fuselage Layout

From the perspective of aerodynamics, the airframe should be streamlined in order to minimize unnecessary induced drag.

During subsonic flight, the shape of the nose of the fuselage will affect the value of wave resistance C_{xw}. The round head of the fuselage can significantly reduce its wave resistance.

For subsonic aircraft fuselage nose part must be:

$$l_{nfp} = \lambda_{np} \cdot D_f = 1.65 \times 3.01 = 4.9665m;$$

where: λ −fitness ratio of nose part;

D_f - fuselage diameter.

Based on the fact that the crash of the one Boeing 747-200 (May 25, 2002, China airlines), which was caused due to poor maintenance that put excessive pressure on the fuselage metal. We can learn from this lesson: when choosing a cross-sectional shape, it is very important to consider strength and layout requirements of the fuselage.

Taking the following successful similar airplanes (CRJ-900, ERJ-190, Boeing 737-500) as a reference, we found that the most airplane adopted circular section or he combination of two or more vertical or horizontal series of circles. It not only can ensure the minimal weight, but also the most convenient fuselage cross section shape. In these cases, we have the minimal fuselage skin width.

Geometrical parameters that we concern:

- fuselage diameter D_f;
- fuselage length l_f ;
- fuselage aspect ratio λ_f ;
- fuselage nose part aspect ratio λ_{np} ;
- tail unit aspect ratio λ_{TU} .

Fuselage length is equal:

$l_f = \lambda_f \cdot D_f = 8.91 \times 3.01 = 26.8191(m);$

Fuselage nose part aspect ratio is equal: $\lambda_{fnp} = \frac{l_{fnp}}{D_f} = \frac{4.965}{3.01} = 1.65;$

length of the fuselage rear part is equal: $\lambda_{frp} = 5.1 - \lambda_{fnp} = 3.45;$

length of the fuselage rear part is equal:

$$l_{frp} = \lambda_{frp} \cdot D_f = 3.45 \times 3.01 = 10.3845(m).$$

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

For our prototype cargo airplane fuselage mid-section first of all comes from the size of passenger cabin.

For mid range airplanes we may take the height as: h_1=1.9611m; passenger width for economic class b_p=0.47m; passenger width for business class b_p=0.51m; the distance from the window to the floor h_2=1m; the distance from the luggage boxes to the floor h_3=1.44…1.8m.

Step of formers (bulkheads) in the fuselage construction is in the range of 350...500mm.

For economic class, the single-row seat arrangement is set as 2+2, and the following calculations are about basic parameters of the cabin:

$$B_{cab} = 2\delta + n_1 \cdot b_{2block} + n_2 \cdot b_{aisle} = 2 \times 0.13 + 2 \times 2 \times 0.48 + 1 \times 0.5 = 2.68(m);$$

where: δ - the distance between the seat and wall;

n_1 - the number of two abreast seats;

b_{2block} - the width of two abreast seats;

n_2 - the number of aisles;

b_{aisle} - the width of aisle.

The length of passenger cabin is equal:

$$L_{cab} = L_1 + (n_{raws} - 1) \cdot L_{seatpitch} + L_2 = 1200 + (23 - 1) \times 750 + 300 = 18m;$$

where: L_1 - the distance between first row and front door;

n_{raws} - the number of rows;

$L_{seatpitch}$ - (750...810mm) for ecnomic class;

L_2 - the distance between final row and rear door.

As for business class, the single-row seats are also set as (2+2) . And the following calculations are about basic parameters of the cabin:

$$B_{cab} = 2\delta + n_1 \cdot b_{block} + n_2 \cdot b_{aisle} = 2 \times 0.13 + 2 \times (5.2 \times 2) + 1 \times 0.45 = 2.79(m);$$

where: δ - the distance between the seat and wall;

n_1 - the number of two abreast seats;

b_{2block} - the width of two abreast seats;

n_2 - the number of aisles;

b_{aisle} - the width of aisle.

The length of passenger cabin is equal:

$$L_{cab} = L_1 + (n_{raws} - 1) \cdot L_{seatpitch} + L_2 = 1200 + (4 - 1) \times 850 + 300 = 4.05(m);$$

where: L_1 - the distance between first row and front door;

n_{raws} - the number of rows;

$L_{seatpitch}$ - (840...870mm) for ecnomic class;

L_2 - the distance between final row and rear door.

1.3.3. Galleys and buffets

International standards stipulate that if the aircraft is in a mixed layout, two plates must be made. If the flight time is less than 3 hours, but no food provided to the passengers, it this case, please provide a cupboard for water and tea. If the flight time is less than 1 hour, the air tickets buffets and restrooms will not be supplied. Kitchen cabinets must be loacted at the door, preferably with a separate door between the cockpit and passengers or cargo. Snacks and food cannot be placed near toilet facilities or connected to a wardrobe.

Following, we need to calculation some necessary parameters about galleys and the food mix,following

The volume of galleys (buffets) is equal:

$$V_{galley} = 0.1 \cdot n_{pass} = 0.1 \times 106 = 10.6(m^3);$$

The area of galleys (buffets) is equal:

$$S_{galley} = \frac{V_{galley}}{H_{cab}} = \frac{10.6m^3}{1.9611m} = 5.41(m^2);$$

According to the passenger seats arrangement, it's best to set up a galley in the front cabin and rear cabin respectively.

The specification of front galley 1: $0.6m \times 1.1m \times 1.97m$;

The specification of rear galley 2: $2.6m \times 1.8m \times 1.97m$;

$$S_{galley} = S_{galley1} + S_{galley2} = 2.6 \times 1.8 + 0.6 \times 1.1 = 5.34(m^2) < 5.41(m^2);$$

Food is provided for passengers every 3.5...4 hours of flight. And the weight of the food provided each time should be about 0.62 kg.

$$t = \frac{flight\,range}{cruise\ speed} + 0.5h = \frac{4537}{829} + 0.55 = 5.97(h) \approx 6(h);$$

$$n = \frac{t}{4} = \frac{6h}{4} = 1.5;$$

where:

t - duration of the flight;

n - the times about fooding the passenger.

The scheme about food organzation each time:

breakfast, lunch or dinner - 0.45kg;

tea or water - 0.17kg.

1.3.4. Lavatories

Number of lavatory facilities are determined by the number of passengers and flight duration. The international standards stipulate that when the duration of the flight exceeds 4 hours, every 40 passengers should be equipped with a toilet.

So the number of lavatories should be equal:

$$n_{lav} = \frac{n_{pass}}{40} = \frac{106}{40} > 2 = 3;$$

The area of the lavatory: $S_{lav} = 1.5m^2$.

The specification of the lavatory: $1.5m \times 1m$.

1.3.5. Layout and calculation of basic parameters of tail unit

One of the most important tasks of the aerodynamic layout is to select the rear wing to be placed. It is related to the longitudinal static stability. Good longitudinal static stability enables the aircraft to automatically return to a stable state when disturbed. In order to ensure the longitudinal stability during overload, when designing the position of the center of gravity, it should be placed in front of the focus of the aircraft.

The next step is to determine the geometric parameters of the aircraft tail unit. The geometric parameters L_{htu} and L_{vtu} values will be affected by many factors: the length of the fuselage nose and tail, the position of the swept wings and the wings. Of course, aircraft stability and control conditions are also a factor that affects the values of L_{htu} and L_{vtu}.

The relationship between the L_{HTU} and b_{MAC} is: $\frac{L_{HTU}}{b_{MAC\ htu}} \approx (2.5\sim3.5)$.

So, in the first approach we get the L_{VTU} and L_{HTU} from the prototype:

$$L_{VTU} = 18.724m;\ L_{HTU} = 18.422m;$$

Area of vertical tail unit is equal:

$$S_{VTU} = \frac{l_w \cdot S_W}{L_{VTU}} \cdot A_{VTU} = \frac{30.3\times103.37}{18.724} \times 0.10 = 16.73(m^2);$$

$$b_{MAC\ htu} = \frac{L_{HTU}}{2.5} = \frac{18.422}{2.5} = 7.4(m);$$

$$S_{HTU} = \frac{b_{MAC} \cdot S_W}{L_{HTU}} \cdot A_{HTU} = \frac{7.4\times103.37}{18.422} \times 0.70 = 29.07(m^2).$$

where: L_{htu} and L_{vtu} - lenght of horizontal and vertical empennage, l_w and S_w - wingspan and area of the wing, A_{htu} and A_{vtu} - coefficients of static moments.

Determination of the elevator area and rudder area:

Elevator area:

$S_{elevators} = (0.3\sim0.4)S_{HTU} = 0.35 \times 24.35 = 8.5225(m^2);$

Rudder area:

$S_{rudder} = (0.35\sim0.45)S_{VTU} = 0.4 \times 16.73 = 6.692(m^2);$

Choose the area of aerodynamic balance:

Elevator balance area is equal:

$S_{aera\ balance} = (0.15\sim0.23)S_{elevator} = 0.2 \times 8.5225 = 1.7045(m^2);$

Rudder balance area is equal:

$S_{aera\ balance} = (0.15\sim0.23)S_{rudder} = 0.18 \times 6.692 = 1.20456(m^2);$

The area of elevator trim tab:

$S_{te} = (0.08 \sim 0.12)S_{elevators} = 0.10 \times 8.5225 = 0.85225(m^2)$;

The area of rudder trim tab is equal:

$S_{tr} = (0.04 \sim 0.06)S_{rudder} = 0.05 \times 6.692 = 0.3346(m^2)$;

The choose of the tapper ratio of horizontal and vertical tail unit:

For planes M<1 corresponds to η_{htu} = 2...3; η_{vtu} = 1…3.3;

Aspect ratio of horizontal and vertical tail unit we may recommend:

For subsonic planes λ_{vtu} = 0.8...1.5; λ_{htu} = 3.5...4.5;

Determination of horizontal and vertical tail unit chords b_{tip}, b_{MAC}, b_{root}:

Tip chord of horizontal stabilizer is:

$b_{tHTU} = \frac{b_{0HTU}}{\eta_{HTU}} = \frac{3.215}{4} = 0.80375(m)$;

Root chord of horizontal stabilizer is:

$$l_{HTU} = (0.32 \sim 0.5)L_{wing} = 0.4 \times 30.3 = 12.12(m);$$

$$b_{0HTU} = \frac{2 \cdot S_{HTU} \cdot \eta_{HTU}}{(1+\eta_{HTU}) \cdot l_{HTU}} = \frac{2 \times 24.35 \times 4}{(1+4) \times 12.12} = 3.215(m).$$

Tip chord of vertical stabilizer is:

$$b_{tVTU} = \frac{b_{0VTU}}{\eta_{VTU}} = \frac{5.624}{4.4} = 1.278(m);$$

Root chord of vertical stabilizer is:

$$l_{VTU} = (0.14 \sim 0.2)l_{wing} = 0.16 \times 30.3 = 4.848(m);$$

$$b_{0HTU} = \frac{2 \cdot S_{VTU} \cdot \eta_{VTU}}{(1+\eta_{VTU}) \cdot l_{VTU}} = \frac{2 \times 16.73 \times 4.4}{(1+4.4) \times 4.848} = 5.624(m).$$

Taking the successful aircraft as a reference, the sweepback angle of the empennage should be taken as 3...50˚, which is larger than the sweepback of the wing.

So: χ_{HTU} = 37 ˚; χ_{VTU} = 42 ˚.

1.3.6. Landing gear design

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

Main wheel axel offset is:

$e_g = (0.15 \sim 0.2) b_{MAC} = 0.17 \times 3.822 = 0.64974 (m);$

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

Landing gear wheel base comes from the expression:

$$B_g = (0.3 \sim 0.4) L_f = 0.35 \times 36.24 = 12.684 (m).$$

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

Front wheel axial offset will be equal:

$$B_{ng} = B_g - e_g = 12.684 - 0.64974 = 12.03426 (m);$$

Wheel track is:

$$T = (0.4 \sim 0.7) B_g = 0.49 \times 12.684 = 6.22 (m) ;$$

In order to prevent the side nose-over, the value T should be > 2H,

where H – is the distance from runway to the center of gravity.

$$H = 2.65m;$$

$$T > 2H = 5.3m;$$

The choice of the wheels of the landing gear is based on the aircraft's take-off weight and operating load; for the front support, we also considered dynamic loading.

The type of aerodynamic devices and the pressure in them are determined by the runway surface. We installed brakes on the main wheels.

The position of C.M. can be taken by height:

- for high planes (with the location of the engines on the wing) c.m. is above the construction horizontal of the fuselage at a distance. The load on the wheel is determined:

K_g = 1.5...2.0 – dynamics coefficient.

Nose wheel load is equal:

$$P_{NLG} = \frac{9.81 \cdot e \cdot K_g \cdot m_0}{B_g \cdot z} = \frac{9.81 \times 0.64974 \times 1.75 \times 50101}{12.684 \times 2} = 22029.6 (N);$$

Main wheel load is equal:

$$P_{MLG} = \frac{9.81 \cdot (B_g - e) \cdot m_0}{B_g \cdot z} = \frac{9.81 \times (12.684 - 0.64974) \times 50101}{12.684 \times 2 \times 2} = 116578.528 (N);$$

Where n and z – number of the number of supports and wheels on one support, respectively.

For the choice of tires, type III tires are often used by modern aircraft. It is commonly used for light aircraft with landing speeds of 160 miles per hour (mph) or less. Therefore, it can well meet the requirements of the new aircraft designed. Type III tires are relatively low-pressure tires. Compared with the total width of the tire, the rim diameter is small. The selection and size of tires are shown in Table 1.5.

Table 1.5 - Avition tires for prototype

Main gear		Nose gear	
Tire size (inch)	Ply rating	Tire size（inch）	Ply rating
41×16	20	24×7.7	16

1.3.7. Power plant

The General Electric CF-34 is a civilian high-bypass turbofan engine which is developed form its TF military engine. It is dual rotor turbofan engine with 3-stage axial low compressor, 9-stage high compressor, an annular combustion chamber, a single-stage high pressure turbine and 4-stage low pressure turbine. It can supply 89 kN thrust, with a high bypass ratio. Nowadays, the CF-34 is used on a number of business and regional jets, including the bombarder CRJ series, the Embraer E-jets and the chinses ARJ 21.

Table 1.6 – Types of the engine of the aircraft

Model	Thrust	Bypass ratio	Dry weight
GE CF34-10E	89KN	5.4:1	1700 kg
GE CF34-10E	89KN	5.4:1	1700 kg

1.4. Determination of the aircraft centre of gravity position

Layout and centering are two interrelated parameters. In order to ensure that the aircraft achieved the required degree of static stability and controllability, its center of gravity which is expressed as the percentage of the MAC length must be in a certain range. And according to the datas from the successful design of aircrafts such as embraer E190, A318 and boeing 737, the range of centering should be within the 0.18 to 0.30.

During the operation of the aircraft, by simply changing the fuel load (such as consumption and transfer) and loading, the position of the center of gravity of the aircraft may change. The center of gravity of the aircraft before and after the change must be as close as possible to ensure the minimum margin required for the static stability of the aircraft.

The maximum allowable front centering of the aircraft is determined by the efficiency of its longitudinal controls (balancing). The greater the efficiency of the longitudinal controls, the easier it is to accept the front centering.

In order to effectively reduce unnecessary weight on the aircraft, the idea of combining functions of elements can be adopted-the principle of using the same structural element or unit to achieve multiple functions in the fuselage layout. For example, connectors and hatches can perform technical and operational functions; reinforced bulkheads are suitable for fuselages connected by vertical tails and horizontal nacelles where engines are installed. And by doing so, you can get a larger volume inside the aircraft to hold the cargo (unit).

1.4.1. Determination of centering of the equipped wing

When considering the quality of the equipped wing, we recorded the quality of the structure of the wing itself, the quality of the equipment in the wing, and the quality of fuel. Whether it's the nose gear attached to the fuselage or the main landing gear attached to the wing, we record them all.

We assume that the nose point of the average aerodynamic chord (MAC) is the origin of the coordinate XOY, and the center of mass of the aircraft is the projection of the origin. The direction of the airplane end point is the positive direction. Next, we suppose that our projection plane is symmetric on the Y axis, so we only determine the coordinates of the center of gravity X. The power center of the equipped wing is defined by the following formula:

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

Table 1.7 - Trim sheet of equipped wing masses

№	Object name	Mass		C.G. coordinates X_i,м	Moment of mass, kg*m
		Units	Total mass m_i		
1.	Wing (structure)	0.10931	5476.54	1.64	9000.47
2.	Fuel system,50	0.0075	375.75	1.64	617.54
3.	Airplane control, 30%	0.00219	109.72	2.29	251.61
4.	Electrical equipment, 30%10%	0.00335	167.84	0.38	64.15
5.	Anti-ice system, 50%	0.0116	581.17	0.38	222.12
6.	Hydraulic systems, 50%	0.01351	676.86	2.29	1552.19
7.	Power Plant	0.09495	4757.09	-2.39	-11346.61
Equipped wing without landing gear and fuel					
9.	Nose landing gear	0.003966	198.70	-10.58	2102.63
10.	Main landing gear	0.035694	1788.31	2.10	3759.20
11.	Fuel	0.25777	12914.53	1.64	21224.52
	Total	0.53984	39101.51	0.70	27447.82

$X_w = \sum m_i \cdot X_i / \sum m_i = 0.7004$ m.

Where – Xw the center of the equipped wing.

1.4.2. Determination of centering of the equipped fuselage

In the calculation process of the device body, we set the coordinate origin on the projection of the top of the nose on the horizontal axis. Table 1.8 lists the relevant parameters of the fuselage structure along the x-axis.

The central gravity coordinates of the equiped fuselage are determined by following formula:

$$X_f = \frac{\Sigma m_i^{/} X_i^{/}}{\Sigma m_i^{/}}; \qquad (1.1)$$

where X_i – fuselage center of gravity coordinate;

$\sum m_i$ – sum of total mass of fuselage.

Table 1.8 - Trim sheet of equipped fuselage masses

№	Objects names	Mass		Center of gravity coordinates Xi, м	Moment of mass
		Units	Total mass		
1.	Fuselage	0.08332	4174.41	18.12	75640.40
2.	Horizontal tail	0.01311	656.82	33.60	22069.29
3.	Vertical tail	0.01352	677.37	33.72	22840.76
4.	Radar	0.0034	170.34	2.94	500.30
5.	Radio equipment	0.0025	125.25	2.94	367.87
6.	Instrument panel	0.0059	295.60	2.94	868.17
7.	Aero navigation equipment	0.0051	255.52	2.94	750.45
8.	lavatory1(14%)	0.00147	73.65	6.17	454.19
9.	lavatory2(14%)	0.00147	73.65	6.17	454.19
10.	lavatory3(14%)	0.00147	73.65	27.02	1989.91
11.	galley 1(29%)	0.003045	152.56	4.70	716.87
12.	galley 2(29%)	0.003045	152.56	27.02	4121.95
13.	Aircraft control system 70%	0.00511	256.02	18.12	4639.01
14.	Hydro-pneumatic sys 30%	0.00579	290.08	25.37	7358.87
15.	Electrical equipment 70%	0.03015	1510.55	18.12	27371.08
16.	Not typical equipment	0.0019547	97.93	27.02	2646.13
17.	lining and insulation	0.0073	365.74	18.12	6627.16
18.	Additional equipment	0.002	100.20	10.50	1052.12
19.	operation items	0.02109	1056.63	10.28	10861.10

Contiuaton of the table 1.8

20.	Anti-ice system25%	0.0058	290.59	28.99	8424.66
21.	Air-conditioning system 25%	0.0058	290.59	18.12	5265.41
22.	passenger seats (business)	0.001437	72.00	5.32	382.65
23.	passenger seats (economic class)	0.01497	750.01	16.62	12465.20
24.	seats of flight attendant	0.0002395	12.00	10.28	123.34
25.	seats of pilot	0.0005988	30.00	3.50	105.00
26.	Passengers(business)	0.01168	585.18	5.32	3110.23
27.	on board meal	0.002624	131.47	27.02	3552.05
28.	baggage, cargo, mail	0.078351	3925.46	18.12	71129.40
29.	crew	0.002595	130.01	3.00	390.04
30.	Passengers(economy)	0.12584	6304.71	16.62	104784.28
Total		0.54786	12863.10	10,30	132495,32
TOTAL fraction		1	11076.83	16.52	182966.00

We can find fuselage center of gravity coordinate X_f:

$$X_f = \sum m_i \cdot X_i / \sum m_i = 16.52 \text{ m.}$$

After we determined the center of gravity of fully equipped wing and fuselage, we construct the moment equilibrium equation relatively fuselage nose:

$$m_f \cdot x_f + m_w \cdot (x_{MAC} + x_w) = m_0 \cdot (x_{MAC} + C), \qquad (1.2)$$

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 mean aerodynamic chord leading edge to the center of gravity point, determined by the designer.

C = (0,23...0,32) $\mathbf{B_{MAC}}$ - high wing.

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

$$X_{MAC} = \frac{m_f x_f + m_w x'_w - m_0 C}{m_0 - m_w} \qquad (1.3)$$

$$X_{MAC}=\frac{m_f x_f+m_w x'_w-m_0 C}{m_0-m_w}=\frac{214513.3+398408-50101\times 0.25\times 3.822}{50101-13933.3}$$
$$=15.623(m)$$

Table 1.9 - Calculation of center of gravity positioning variants

Name	Mass, Kg	Coordinate	Mass moment
Object	m_i	X, m	Kg.m
Equipped wing (without fuel and landing gear)	12144.98	15.13	183750.73
Nose landing gear (extended)	198.70	4.52	897.75
Main landing gear (extended)	1788.31	17.20	30762.60
Fuel/fuel reserve	12914.53	16.74	216234.00
Equipped fuselage (without payload)	12003.70	18.17	218096.10
Passengers of business class	585.18	5.32	3110.23
Passengers of economy class	6304.71	16.62	104784.28
Baggage	3925.46	18.12	71129.40
Crew	130.01	3.00	390.04
Nose landing gear (retracted)	198.70	4.52	897.75
Main landing gear (retracted)	1788.31	17.20	30762.60
Reserve fuel	2570.98	16.74	43047.17

$$X_c=\frac{X_{c\ mass}-X_{mac}}{b_{mac}}\times 100\%;$$

Where: Xc - the centering;

Xc mas - the center of mass.

The calculated result will shown in table 1.10.

Table 1.10 - Airplanes center of gravity position variants

Variants of the loading	Mass, kg	Moment of the mass, kg*m	Center of mass, m	Centering
Take off mass (L.G. extended)	49995.59	829155.11	16.58	0.25
Take off mass (L.G. retracted)	49995.59	829155.11	16.58	0.25
Landing weight (LG extended)	39652.04	655968.29	16.54	0.24
Ferry version	39180.23	650131.21	16.59	0.25
Parking version	26135.69	433507.17	16.59	0.25

Conclusion to the project part

By comparing with similar aircraft on the market (ERJ-190, A318, CRJ-900), we can get that the medium-range 106-seat civil regional passenger aircraft designed this time fully meets the requirements of the project's scope of responsibility (even exceeds the basic level).

In this design, we considered and designed the main geometric parameters of the aircraft structure design, such as wing characteristics, fuselage structure, tail components and landing gear parameters. After completing the design of the wing and fuselage layout, we calculated the center of gravity of the aircraft, including the mass of the wings, fuselage and other parts of the aircraft.

The range of possible center of gravity positions has been found. It satisfies the aircraft's requirements for longitudinal stability and controllability.

PART 2
FLEXIBLE CONVEYOR DESIGN

2.1 Analysis of existing flexible conveyor

The conveyor belt system is a mechanical device that can move goods from one location to another. Because of their ability to adapt to the transportation of various shapes and materials, and their efficiency and convenience. they have became popular in the commodity handling and packaging industries.

For the baggage loading and unloading of the regional aircraft, the flexible conveyor has better functions than the traditional belt loader (its loading and unloading efficiency is nearly 25%-30% higher than that of the traditional belt conveyor).

There exist two main types of flexible conveyors, powered roller conveyor and gravity roller conveyor. As for the aircraft baggage loading and unloading, it was decided to adopt the powered roller conveyor which can save more vertical space and supply sufficient controllablity.

The roller conveyor has a series of rollers mounted on bearings, which move at fixed or fixed intervals on two side frames. The distance between the rollers depends on the size of the unit to be loaded, so there are at least three rollers carrying the load at any time. For the flexible roller conveyor, the choice of the connection method between the rollers is the most essential portion to realize its function (as shown in the figure 2.1) [1]

Figure 2.1 – Typical conveyor system

2.2 Requirements to a new machine

It is very necessary to design new machines according to actual working conditions and problems that have been exposed by traditional working methods.

The first problem is that in traditional loading and unloading systems, workers need a lot of time to load and unload luggage. It requires high human cost and time cost. Secondly, traditional transportation systems such as ball pads and roller pads add unnecessary weight, which increases the fuel consumption of aircraft and is uneconomical. Thirdly, during the luggage transfer process, the floor and luggage may wear out. Finally, the staff needs to bend over to work in the cargo hold --- pull the luggage to the correct position. This long-term exercise will hurt the shoulders of the workers.

Accroding to these consideration, following functions should be achieved:

1. Faster turn around. Improve the effciency of the baggage transportation.
2. Save aircraft fuel. Reduce the unnecessary weight of the aircraft baggage transportation system.
3. Less damage. Do less wear-and-tear damage to the floor and baggages.
4. Improve working condition. Equipment requires less physical exertion and causes less harmful, long-term physical impact on human body.

So that, for my designed equipment, the flexible conveyor system requirements are as follows:

1. Able to handle a 270 (10×27) kg load.
2. The maximum rotating speed can up to 100 r/min.
3. Be able to accelerate in 1 second.
4. Allows frequent start and stop.
5. Low gearmotor maintenance.

2.3 Preliminary design of the flexible conveyor

2.3.1. Roller length design

According to the regulation of the aircraft, the length, width and height of the baggage should be corresponed to $1000mm \times 600mm \times 400mm$. Based on that, the width of the load equal to the 600mm.

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

$$L = W + \Delta B = 600 + 200 = 800\ (mm);$$

where: W - width of the load;

ΔB - width desire (100-200 mm).

2.3.2. Roller diameter design

As for the diameter calculation of the rollers, it's significant to settle the initial datas of the equip:

The length of the conveyor is 10m;

the load of the conveyor is 270 kg;

transmisson mode is chain transmisson;

the roller speed 0.5m/s;

The dynamic friction of the surface glue on the roller is 0.5.

Sliding friction of the rollers and baggage: $F_s = \mu G = 0.5 \times 270 \times 10 = 1350\ (N)$.

Required transmission power: $P_r = F_s V = 1350 \times 0.5 = 675\ (W)$.

For the material of the rollers, Aluminum Wrought Alloy 2014-T6 could satisfy the reuqirements well. And the ultimated shear stress $\tau = 184MPa$. Based on the safty consideration, we take the allowable shear stress $[\tau] = 160MPa$.

Figure 2.1 - Properties of the material

material	Yield strength(ksi)			Ultimate strength(ksi)		
	Tens.	Comp.	shear	Tens.	Comp.	shear
Aluminum Wrought Alloy 2014-T6	60	60	25	686	68	42
Aluminum Wrought Alloy 6061-T6	37	37	19	42	42	27
Steel alloy structure A36	36	36	-	58	58	-
Steel alloy structure 304	30	30	-	75	75	-
Plastic kevlar 49	-	-	-	104	70	10.2

Overall, the diameter calculated by following formula:

$$d \geq \sqrt{\frac{9.55\times10^6}{0.2[\tau]}}\sqrt{\frac{P}{n_{roller}}} = \sqrt{\frac{9.55\times10^6}{0.2\times160}} \times \sqrt{\frac{675\times10^{-3}}{100}} = 44.6(mm);$$

where: P – power transmitted by the rollers;

n_{roller} – rotating speed of the rollers (take it as 100 r/min).

In order to simplify the calculation and to use standard bar, we take the diameter as 50 mm.

2.3.3. Roller thickness

The size of the package in this design is 1000mm×600mm, and during the transportation process, there are at least three rollers to support. In order to calculate the maximum moment, it's very significant to determined the uniform load which is the force uniformly distributed on the structure.

So, the uniform load of each roller is:where

$$q = \frac{\frac{G_1}{3}}{a} = \frac{(27+30)\times 10/3}{0.6} = 316.67\ (N/m),$$

where: q – load factor of the each roller;

G_1 – weight of the three rollers and one baggage;

a –the baggage width.

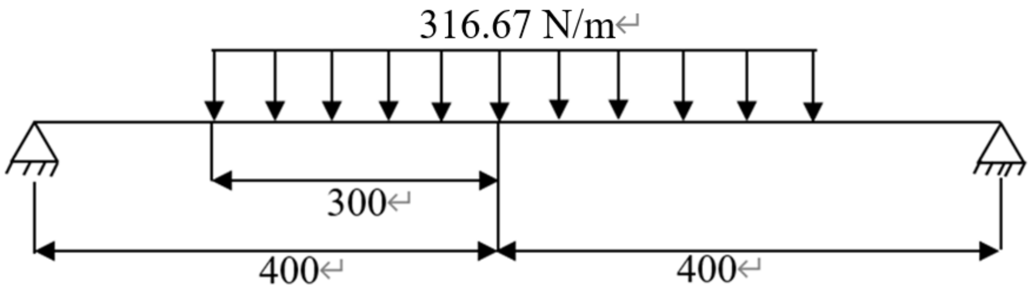

Figure 2.2 - Load distribution diagram of roller

According to the figure 2.2, we can calculated the maximum moment M_{max}:

$$M_{max} = \frac{1}{2}\cdot\frac{G_1}{3}\cdot\frac{L}{2} - q\cdot\frac{a}{2}\cdot\frac{a}{4} = \frac{570}{6}\times 0.4 - 316.67\times 0.3\times\frac{0.6}{4} = 23.75\ (N\cdot m);$$

$[\sigma]$ - is the allowable stress of the material, which calculated through formula $[\sigma] = \frac{\sigma_s}{n_s}$. Accoring to the figure 2.2, the yield strength of Aluminum Wrought Alloy 6061-T6 is 252 Mpa. And the safety factor of the material under static load can be 1.2~2.5. So:

$$[\sigma] = \frac{\sigma_s}{n_s} = \frac{252}{2.5} = 100.8\ (MPa).$$

According to the knowledge of the material mechanics, we can calculate the bending section coefficient of the hollow roller by using following ring section formula:

$$W = \frac{\pi}{32} d^3 \left(1 - \left(\frac{d_n}{d}\right)^4\right);$$

where: W- bending section coefficient of the hollow roller;

d – outer diameter of the roller;

d_n – the inside diameter of the roller.

Finally,

$$\sigma_{max} = \frac{M_{max}}{W} = \frac{23.75}{\frac{\pi}{32} \times 0.05^3 \left(1 - \left(\frac{d_n}{0.05}\right)^4\right)} \leq [\sigma] = 100.8\ (MPa);$$

The result is $d_n \leq$49mm. We can know that this is a very safe design, so we can set the thickness of the roller arbitrarily. And we take the inside diameter as 40 mm. The thickness is $\delta = 5mm$.

2.4 Roller bearing

2.4.1. Bearing selection

In roller rotation, the roller mainly bears the radial force and has slight axial force. So the bearing bears the radial force dominantly.

Based on previous calculation, we get the length of the roller is 800mm and the roller's outer diameter is 60mm. Meanwhile, the baggage 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).

$$F_r = \frac{G_1}{6} = \frac{570}{6} = 95\ (N);$$

$$F_a = 0\ (N).$$

Dynamic load can be calculated by formula:

$$P = X \cdot F_r + Y \cdot F_a = 1 \times 95 + 0 \times 0 = 95\ (N);$$

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.

Table 2.1 - Load factors of the single row bearings

Bearing types	Relative axial load		Single row bearing			
			$F_a/F_r \leq e$		$F_a/F_r > e$	
	F_a/Cor	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

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:

$$C_r = \frac{f_p \cdot p}{f_t}(\frac{60n_m}{10^6}L_h)^{1/\epsilon} = \frac{1.0 \times 95}{1.0} \times (\frac{60 \times 100}{10^6} \times 50000)^{\frac{3}{10}} = 525.8(N);$$

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).

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

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

From the machanical design manual: The 61802 bearing $C_r = 2.1kN \geq 0.525kN$; the inner diameter of the bearing is 15mm and the outer diameter is 24mm. Thichness of the bearing is 5mm.

2.4.2. Bearing check

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

$$L_h = \frac{10^6}{60n_m}(\frac{f_t C_r}{f_p P})^{\epsilon} = \frac{10^6}{60 \times 100}(\frac{1.0 \times 2100}{1.0 \times 95})^{\frac{10}{3}} = 4761959\ (h) > 50000(h).$$

The selected bearing life meets the requirements.

2.5 Calculation of flexible joint

2.5.1. General dimension

The flexible conveyor can be adapted 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 roller and the roller is very important.

Firgure 2.3 - 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:

$$d_r \geq \frac{\frac{\pi}{2}L+(\mathrm{n}-1)d}{n-1} = \frac{\frac{\pi}{2}\times 800+(31-1)\times 50}{31-1} = 91.89(mm)$$

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

$$d_r = 92\ (mm);$$

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(take it as 16).

We set the distance between the two roller diameters to be 10mm under normal non-working conditions. Therefore, we can calculated the number of the rollers(z) by length of the conveyor divide 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:

$$L_{ex} = d(z-1) = 92 \times (166-1) = 15.3\ (m);$$

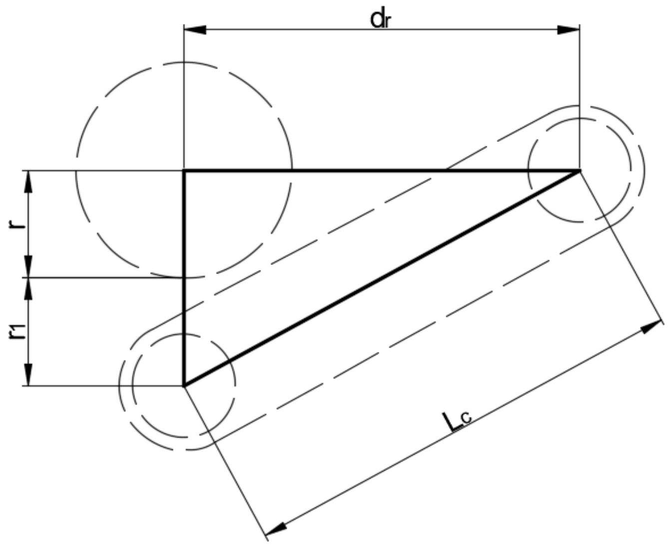

Figure 2.4 - Length of connecting piece calculation

Form the figure 2.4, we can get that the length of connecting piece can be calculate by $L_c = \sqrt{(d_r)^2 + (r + r_1)^2}$.

$$d_r = 92\ (mm);$$

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

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,

$$L_c = \sqrt{(d_r)^2 + (r + r_1)^2} = \sqrt{92^2 + 50^2} = 105\ (mm);$$

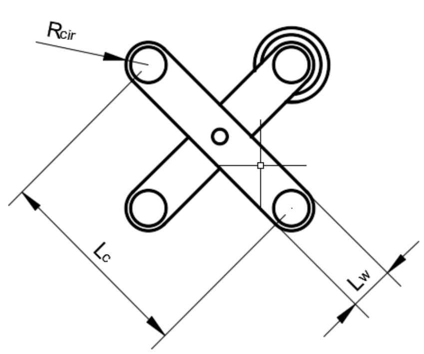

Figure 2.5 - Dimension of the connecting piece

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

$$L = 2R_{cir} + L_c = 2 \times 15 + 105 = 135\ (mm).$$

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.

2.6 Calculation and selection of motor

2.6.1. Calculation of motor power

The motor power could be calculated by following formula:

$$N = N_1 + N_2;$$

where: N_1 – the power required to overcome the friction of the roller;

N_2 – the power required to overcome the interial resistance of the baggage.

It's significant to know the resistance moment of the bearing at the roller journal (W_1) and the resistance of the baggage along the roller (W_2).

$$W_1 = g\left(m_{baggages} + z \cdot q\right)\mu\frac{d}{2} = 9.8 \times (270 + 166 \times 10) \times 0.015 \times \frac{0.05}{2} = 7.09\ (W);$$

where: $m_{baggages}$ - the maximum load of the conveyor;

z - the number of the rollers;

q - the mass of each roller;

g - gravity coefficient;

μ - rolling friction coefficient (from table 2.3, it's 0.015);

d - outer diameter of the bearing.

$$W_2 = g \times m_{baggages} \times k \div 100 = 9.8 \times 270 \times 0.05 \div 100 = 1.32\ (W);$$

where: g - gravity coefficient;

$m_{baggages}$ - the maximum load of the conveyor;

k - rolling friction coefficient between baggages and rollers (from table 2.4, it's 0.05).

Tabel 2.3 - Rolling friction coefficient

Working condition	Enviroment	Sliding bearing	Rolling bearing
Good	clean and dry indoor work without abrasive dust	0.1~0.15	0.01~0.015
Medium	Normal temperature with a small amount abrasive dust	0.15~0.20	0.01~0.02
Bad	Work outdoor where there is a possibility of losing the friction surface or having a lot of abrasive dust	0.20~0.25	-

Table 2.4 - Rolling friction coefficient between baggages and rollers

Friction material	K
Mild steel - Mild steel	0.05
Hardened steel - Hardened steel	0.01
Cast iron - Cast iron	0.05
Timber - Steel	0.03~0.05
Timber - Timber	0.05~0.08
Steel wheel – Steel wheel	0.05

The power required to overcome the friction of the roller:

$$N_1 = (W_1 + W_2)\omega = (7.09 + 1.32) \times 160 = 1345.6\ (W);$$

where: ω - the rotating speed of the bearing.

The power required to overcome the interial resistance of the baggage:

$$N_2 = \frac{m_{baggage}V^2}{t_s} = \frac{270 \times 0.5^2}{1} = 67.5\ (W);$$

where: t_s - strating time of the motor(t_s = 1s);

V - the velocity of the roller.

So that;

$$N = N_1 + N_2 = 1345.6 + 67.5 = 1413.1\ (W)$$

Overall, we can calculate the motor rated power:

$$N_J = \frac{N}{\eta} = \frac{1413.1}{0.5} = 2.826\ (kW);$$

where: η – machincial efficiency of the conveyor;

N_J – the rated power of the motor.

2.6.2. Selection of the motor

From the previous calculations, we get the required rated power and required speed of the motor. Therefore, the actual rated power and speed of the selected motor should be greater than the previously calculated values.

Table 2.5 - Y series motors relative parameter

model	Rated power/kw	Rated torque/Nm	Rated speed/rpm	Rated current/A	effectiveness	Power factor
Y90S-6	0.75	2	910	2.3	72.5	0.70
Y90	1.1	2	910	3.2	73.5	0.72
Y100L-6	1.5	2	940	4.0	77.5	0.74
Y112M-6	2.2	2	940	5.6	80.5	0.74
Y132S-6	3	2	960	7.2	83.0	0.76

From the table 2.5, we find that the rated power of the motor Y132S-6 $N_J = 3\ kW \geq 2.826\ kW$. The rated speed of the motor Y112M-6 is 940 rpm which is bigger that the 160 r/min. So, motor Y112M-6 could satisfied the requirements well.

Conclusion to the special part

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

In the overall size design of the conveyor, full consideration is given to the size of the luggage and the strength of the material.

In the bearing strength calculation, strive to achieve the maximum working life.

Of course, the design of the connection also satisfies the realization of the function as much as possible.

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

General Conclusion

In this paper, the preliminary design of the aircraft and flexible conveyor is carried out.

Taking the mainstream regional jets in the current market as a reference, we have designed a 106-seat mid-range civil airliner. The various parts of the aircraft wing (length, sweep angle, aileron, etc.) were selected and calculated.

A low-level wing design with a sweep angle is adopted. In order to achieve good aerodynamic performance of the aircraft wing, we decided to adopt slotted flaps and later airfoils.

The fuselage layout is mainly divided into economy class and business class. Among them, the width of the corridor and the arrangement and spacing of the seats are selected through calculation.

As for the aircraft's center of gravity and landing gear. We use the most classic first three-point landing gear to ensure the safety of take-off and landing. We also calculated the center of gravity under various conditions (full-load take-off, landing, etc.).

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

According to the specifications of the baggage checked by the plane, the overall size of the drum is designed.

In the process of bearing selection and strength design, full consideration is given to safety and bearing service life.

Of course, the design of the connection also satisfies the realization of the function as much as possible.

Finally, when calculating and selecting the motor, based on the concept of redundancy, a 1.5kW motor was selected to ensure smooth transportation.

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INITIAL DATA AND SELECTED PARAMETERS

Name: Wang Haohao Supervisor: Karuskevich M.V.

Passenger Number	106
Flight Crew Number	2
Flight Attendant or Load Master Number	3
Mass of Operational Items	1056.54
Payload Mass	11077.00
Cruising Speed	829
Cruising Mach Number	0.7785
Design Altitude	11.30
Flight Range with Maximum Payload	4537
Runway Length for the Base Aerodrome	2.20
Engine Number	2
Thrust-to-weight Ratio in N/kg	3.4400
Pressure Ratio	29.00
Assumed Bypass Ratio	5.50
Optimal Bypass Ratio	5.50
Fuel-to-weight Ratio	0.2500
Aspect Ratio	8.91
Taper Ratio	4.00
Mean Thickness Ratio	0.12
Wing Sweepback at Quarter Chord	27.0
High-lift Device Coefficient	0.93
Relative Area of Wing Extensions	0.01
Wing Airfoil Type	
Winglets	
Spoilers	
Fuselage Diameter	3.01
Fitness Ratio	10.00
Horizontal Tail Sweep Angle	31.0
Vertical Tail Sweep Angle	42.0

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point	0.44518
Induce Drag Coefficient	0.00915

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

Cruising Mach Number	0.77854
Wave Drag Mach Number	0.78435
Calculated Parameter D_m	0.00581
Wing Loading in kPa (for Gross Wing Area):	
At Takeoff	4.75
At Middle of Cruising Flight	4.10
At the Beginning of Cruising Flight	4.575
Drag Coefficient of the Fuselage and Nacelles	0.00859
Drag Coefficient of the Wing and Tail Unit	0.00917
Drag Coefficient of the Airplane:	
At the Beginning of Cruising Flight	0.02899
At Middle of Cruising Flight	0.02793
Mean Lift Coefficient for the Ceiling Flight	0.44518
Mean Lift-to-drag Ratio	15.94018
Landing Lift Coefficient	1.537
Landing Lift Coefficient (at Stall Speed)	2.305
Takeoff Lift Coefficient (at Stall Speed)	1.931
Lift-off Lift Coefficient	1.409
Thrust-to-weight Ratio at the Beginning of Cruising Flight	0.584
Start Thrust-to-weight Ratio for Cruising Flight	2.542
Start Thrust-to-weight Ratio for Safe Takeoff	3.231
Design Thrust-to-weight Ratio	3.392
Ratio $D_r = R_{cruise} / R_{takeoff}$	0.787

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

Takeoff	36.0362
Cruising Flight	58.0192
Mean cruising for Given Range	61.9339

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.03497
Block Fuel	0.22280

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.10931
Horizontal Tail	0.01311
Vertical Tail	0.01352
Landing Gear	0.3966
Power Plant	0.10245
Fuselage	0.08332
Equipment and Flight Control	0.13680
Additional Equipment	0.00200
Operational Items	0.02109
Fuel	0.25777
Payload	0.22109

Airplane Takeoff Weight	50101
Takeoff Thrust Required of the Engine	84.97

Air Conditioning and Anti-icing Equipment Weight Fraction	0.232
Passenger Equipment Weight Fraction (or Cargo Cabin Equipment)	0.0172
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.0073
Furnishing Equipment Weight Fraction	0.0105
Flight Control Weight Fraction	0.0073
Hydraulic System Weight Fraction	0.0193
Electrical Equipment Weight Fraction	0.0335
Radar Weight Fraction	0.0034
Navigation Equipment Weight Fraction	0.0051
Radio Communication Equipment Weight Fraction	0.0025
Instrument Equipment Weight Fraction	0.0059
Fuel System Weight Fraction	0.0075

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)	0.0020

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed	264.23
Acceleration during Takeoff Run	2.78
Airplane Takeoff Run Distance	968
Airborne Takeoff Distance	578
Takeoff Distance	1546

CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed	251.02
Mean Acceleration for Continued Takeoff on Wet Runway	0.50
Takeoff Run Distance for Continued Takeoff on Wet Runway	1386.03
Continued Takeoff Distance	1964.41
Runway Length Required for Rejected Takeoff	2033.19

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight	41012
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight	21.6
Descent Distance	49.68
Approach Speed	246.19
Mean Vertical Speed	1.99
Airborne Landing Distance	515
Landing Speed	231.19
Landing run distance	732
Landing Distance	1247
Runway Length Required for Regular Aerodrome	2083
Runway Length Required for Alternate Aerodrome	1771

ECONOMICAL EFFICIENCY

THESE PARAMETERS ARE NOT USED IN THE PROJECT