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

« _____»____________________ 2021 р.
(підпис)

ДИПЛОМНИЙ ПРОЕКТ

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

Тема: «Аванпроект ближньо-магістрального пасажирського літака пасажиромістківстю 68 пасажирів»

Виконав: Ван Цзюньхань

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

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

Київ 2021

MINISRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

Aircraft Design Department

AGREED
Head of department
Dr. Tech. Science, Prof
S.R. Ignatovych
«___» _______ 2021

DIPLOMA WORK

(EXPLANATORY NOTE)
OF EDUCATIONAL DEGREE

«BACHELOR»

Theme: «Preliminary design of the short-range passenger aircraft with 68 passenger capacity »

Performed by: Wang Junhan

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

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

Kyiv 2021

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty

Aircraft Design Department

Educational degree «Bachelor»

Speciality 134 "Aviation and Space Rocket Technology"

AGREED
Head of department
Dr. Tech. Science, Prof
S.R. Ignatovych
«____ » ____________ 2021

TASK

for bachelor diploma work

Performed by: Wang Junhan

1. Theme: «Preliminary design of the short-range passenger aircraft with 68 passenger capacity»

Confirmed by Rector's order from 21.05.21 year № 815/ct

2. Period of work execution 24.05.21 to 20.06.21.

3. Work initial data:

- Maximum payload – m = 32,78 tons;
- flight range with maximum payload – L_{ran}= 1528 km;
- cruise speed – V_{cr} = 510 Km/h at operating altitude H_{op}= 6100 m;
- landing speed – V_{land} = 200.9 km/h.

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

- Analysis and short description of designing aircraft;
- calculation of aircraft masses;
- determination of basic geometrical parameters;
- aircraft layout;
- center of gravity position calculation;
- engine selection;
- special part.

5. List of the graphical materials:

- Aircraft general view (A1 × 1);
- aircraft layout(A1 × 1);
- attachment of conveyor belt(A1 × 1);
- details of conveyor belt(A1 × 1).

6. Calendar Plan

№	Task	Execution period	Signature
1	Task receiving, processing of statistical data	24.05.21	
2	Aircraft take-off mass determination	29.05.21	
3	Aircraft layout	02.06.21	
4	Aircraft centering determination	06.06.21	
5	Graphical design of the parts	08.05.21	
6	Preliminary defence	14.06.21	
7	Completion of the explanation note	14.06.21	

7. Task date: « 24 » 05. 2021

Supervisor of diploma work: ___________ M.V. Karuskevich

(signature)

Task is given for: __________ Wang Junhan

(signature)

ABSTRACT

Explanatory note to the diploma work «Preliminary design of the short-range passenger aircraft with 68 passenger capacity» contains:

66 pages, 13 figures, 11 tables, 10 references and 4 drawings.

Object of the design is development of short-range passenger aircraft with 68 passenger capacity.

The purpose of the diploma work is to provide an estimate of the preliminary design of the aircraft and its design characteristics.

The methods of design are analysis of the advanced prototypes and selections of the most efficient technical decisions for application in new aircraft design.

The design approach is to analyze advanced prototypes and borrow its advanced characteristics and geometric date for the new aircraft design.

The diploma work contains results of the preliminary design, required calculations, drawings of the general view of the short-range passenger aircraft with 68 passenger capacity, aircraft assembly drawings and layout drawings, description of the conveyor belt concept, preliminary design of the conveyor belt.

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

CONTENT

				NAU 21 07W 00 00 00 00 44
Performed by	Wang Junhan			CONTENT
Supervisor	Karuskevich M.V.			
Adviser				
Stand.contr.	Khizhnyak S.			
Head of dep.	Ignatovych S.			

Letter	Sheet	Sheets

402 AF 134

				NAU 21 07W 00 00 00 00 44		
Performed by	Wang Junhan			CONTENT	Letter / Sheet / Sheets	
Supervisor	Karuskevich M.V.					
Adviser					402 AF 134	
Stand.contr.	Khizhnyak S.					
Head of dep.	Ignatovych S.					

LIST OF ABBREVIATIONS

- LG: Landing gear.
- TLG: Tricycle landing gear with front single-strut and two main gears.
- APU: Auxiliary power unit.
- SRA: Short-range airplane.
- CG: Center of Gravity.
- MAC: Mean aerodynamic chord.
- CB: Conveyor belt.
- PB: Passenger baggage.
- IR: Idler roller.

LIST OF DRAWING

№	Name of drawings	Form at	Number of sheets
1	Aircraft general view	A1	1
2	Aircraft layout	A1	1
3	Attachment of conveyor belt	A1	1
4	Details of conveyor belt	A1	1

Introduction

A passenger aircraft is usually defined as an aircraft used to carry multiple passengers or cargo in a commercial service. Usually, the types of aircraft can be divided into two species: wide-body aircraft and narrow-body aircraft. Wide-body aircraft are usually used for long-range, high-load flight, while narrow-body aircraft are usually used for short-range, low-load flight due to its characteristics.

Typically, the seats of short-range aircraft are less than 100 passengers and the flight range is usually less than 2500 km. Usually it will be powered by turbofans or turboprops engine. A short rang aircraft has many advantages: low requirements for airports, short time to turnaround and make-ready, and also has high economy benefit and less cost for maintenance. Nowadays, small scale airlines tend to reduce the size of the aircraft to earn more profit So such small aircraft will have good future prospects and growth rapidly.

The objective of this work is preliminary design of the short-range passenger aircraft with 68 passenger capacity. The main prototype of this work is the ATR-72-600.

To gain this objective the following tasks have been solved:

- Brief description of the main parts of the aircraft;
- geometry calculations for the main parts of the aircraft;
- layout of the aircraft;
- aircraft center of gravity positions range.

The design airplane will strictly follow the airworthiness requirement, rules, and recommendations. To design a suitable aircraft, the following feature should be considered [1]:

- Flight safety;

- good aircraft performance;
- great passenger comfort in flight;
- prices and cost are affordable;
- modern equipment to reduce maintenance cost and improve reliability;
- good in-flight service and adequate entertainment for passengers;
- in-flight emergency equipment.

The International standards on Airworthiness requirements have been used in the process of the aircraft preliminary design.

PART 1. PRELIMINARY DESIGN OF THE PLANE

1.1. Analysis of prototypes and short description of designed aircraft

1.1.1. Choice of the project data

During the preliminary aircraft design stage, some successful designed aircraft could be used as a reference, which means a prototype can be selected for reference to design the aircraft. The following aircraft performance parameters need to be considered while designing an aircraft: aerodynamics, structural strength, aircraft load capacity, aircraft economics, and placement for aircraft equipment. Most of the mentioned aircraft parameters need to be considered with reference to the prototype.

Design of a prototype aircraft is often successful, so their design experience can be used as a reference. Selection of the prototype aircraft should have the similar characteristic to the design aircraft such as the similar takeoff weight, passenger capacity, flight range, fuel consumption and geometrical parameters.

The objective of this work is preliminary design of the short-range passenger aircraft with 68 passenger capacity, so I have chosen from three prototype aircrafts with the same appearance which are ATR-72, Fokker-50 and An-24, compared the technical date of these three aircraft and have chosen one aircraft as the prototype of my design aircraft. Statistic data of prototypes are shown in table 1.1 and table 1.2.

Table 1.1 - Technical data of plane prototype

Name and dimensions	ATR-72	Fokker-50	An-24
MTOW, kg	32785	20820	21000
Crew, numbers	2	2	3
Flight range with MTOW, km	1528	1700	2400
Cruise speed, km/h	510	500	450
Cruise altitude, km	6.1	7.62	8.4
Number and type of engines	2*PW127M turboprop engines	2*PW125B turboprop engines	2*AI-24A turboprop engines
Take off run at MTOW, m	2015	1800	1780

Ending of table 1.1 - Technical data of plane prototype

Landing distance, m	659	1130	1050
Landing speed, km/h	200.91	190	190
Field length for takeoff, km	1.367	1.38	1.39
Power (each engine), kw	1846	1864	1900

Table 1.2 - Geometrical parameters of plane prototypes

Name and dimensions	ATR-72	Fokker-50	An-24
Length of the fuselage, m	27.17	25.25	23.53
Wingspan, m	27.05	29	29.2
Wing area, m^2	61	70	74.98
Aspect ratio	12	12.01	11.7
Sweepback angle, degree	7	6	8
Height at tail, m	7.65	8.32	8.32
Fuselage diameter, m	2.57	2.5	2.9
Wing tapper ratio, m	2	2.25	2.4

An excellent aircraft solution design must have good aerodynamic system, operational performance, center of gravity layout, furniture layout, etc. This will improve the performance, reliability and economic efficiency of the aircraft. The prototype design is often successful, so that the designed aircraft will have the same good flight performance as the prototype aircraft.

The general characteristic of design aircraft such as the shape of the fuselage, wings, tail, and landing gear will not be changed significantly from the prototype. We need to determine the position of the wings relative to the fuselage, the geometry of the fuselage wings and the control systems on the wing. Also, determine the mass and position of each component to satisfy the center of gravity distribution requirements.

Our task is preliminary design of the short-range passenger aircraft with 68 passenger capacity，I have chosen ATR-72 as the prototype for my designed aircraft, because it has following advantages [11]:

- The ATR 72 is lighter and the fuel consumption is less;
- the ATR 72 have fuel burning advantage which leads to lower costs and emissions and could be more optimal aircraft for regional markets;
- the ATR could withstand extreme bad weather during flight due to its high stability;
- the ATR do not need too much takeoff and landing field length;
- the ATR has high cruise speed;
- the ATR has of a big cargo door and it is quite convenience for loading and unloading;
- the ATR has a comfortable passenger experience due to its good furniture and entertainment on the aircraft.

Brief description of prototype aircraft ATR-72. The ATR-72 is a shortrange aircraft, this aircraft is produced by the French manufacturer ATR and generally an aircraft can take 72 passengers and 4 crew members. It is powered by two PW127M turboprop engines which is localed beneath the wing on each side. And it could supply power reach to 1847KW for each engine [6]. Following performance are affirmed for this aircraft: length field for takeoff is 1367m, maximum takeoff weight is up to 23000kg, its cruise altitude is reach to 6.1km, the flight range of ATR-72 is 1528km, the wing employs carbonfibres for 30% to reduce 20% weight. It has two doors in front and tail part, the cargo door is near the nose part and the passenger door near the tail part. Following figures (fig 1.1, fig 1.2) are general external and inner view of my prototype aircraft ATR-72.

Fig 1.1 - General external view of ATR-72 [6]

Fig 1.2 - General inner view of ATR-72 [6]

1.1.2. Brief description of the main parts of the designed aircraft

Fuselage. The fuselage produces less lift and more drag, but it is indispensable for an aircraft [1]. The main function of the fuselage is to support and transmit the loads generated by the wings, tail, and landing gear and to accommodate the crew, flight equipment, furniture, and passengers. It provides protection for passengers by separating them from the external environment.

The designed aircraft presents a semi-monocoque construction which is constructed primarily by alloys of aluminum and magnesium, those components combined together and form a strong, rigid framework. The method of friction weld, rivets and bolt are used to combine components together.

The main components of the fuselage are hoop frames, stringers, longeron, skin, bulkhead, keel, floor frames, and floor beams, most of the structural elements of the fuselage are made of high-strength carbon steel, aluminum sheet, organic glass, composite material and aluminum alloys. Internal braces and the skin itself carry the stress, bulkheads and frames withstand the concentrated load, other structures such as wing and stabilizer will attach on the bulkheads and frames. Longerons are used to taken the bending loads and the stringers are used to give the shape and the attachment of the skin. The cruise altitude of designed plane is 6100m, so the cabin is pressurized with all-metal freestanding, a circular cross-section fuselage will apply on our designed plane because it is easy to manufacture and good for cabin to keep pressurizing.

The fuselage of designed aircraft must follow such requirements [1]:

- Accommodation requirement;
- airworthiness requirement;
- aerodynamic requirement;
- stability and integrity requirement;
- low weight requirement;
- high dynamics and lifetime requirement;
- maintainability requirement.

Fuselage layout. In my designed aircraft, the fuselage will be divided into four parts, nose part, cargo compartment, passenger cabin and tail part. Two seats of pilot are installed in the nose part, the instrument panel, control surface and radio equipment are also installed in the nose part, wide angle window is placed in front of the nose part which could give wide view for pilot to observe the situation on the ground, the nose landing gear is under the floor of nose part, the length of nose part is equal to 3.2 m. Position of cargo compartment is between the nose part and passenger cabin, passenger baggage and other cargo are custodied in the cargo compartment, a big cargo door with the size of 1.2*1.8m is on the left side of fuselage, which could make it more convenient for loading and unloading, one flight attendance seat is in the cargo compartment, length of the cargo compartment is equal to 2.8m. The designed plane has the capacity of 68 passengers, in the passenger cabin, there will be 2*2 passenger seats in one row and divided by one aisle, 17 rows in total in the passenger cabin, in designed plane 27 windows will be installed in each side of the fuselage, there will be two emergency exits, the passenger entry door install in the rear part and one flight attendance seat is behind the passenger entry door. Some emergency equipment also placed in the passenger cabin which includes ropes, oxygen masks, oxygen devices, fire extinguish, first-aid kits, emergency evacuation routes, emergency lighting and a board "EXIT" near each emergency exit. There are two rows of luggage cabinets on the ceiling used to storage passenger baggage, the length of passenger cabin is equal to 15.2m. In my designed plane, there will have several galleys and toilet in the tail part, the geometric dimension of galley and toilet are standard.

The fuselage layout design must follow such requirement:

- Keep the fuselage as small and compact as possible;
- to be symmetric from the top view as far as possible;
- there must be sufficient space to accommodate all the items;
- the location of these equipment must follow the aircraft center of gravity requirement.

Wing structure. The wing structure is a very important part of an aircraft. The function of the wing is to provide lift force for aircraft, to carry the inertia loads from the engine, and to store aviation fuel. The wing of designed plane is high wing, due to it has turboprop engine and need clearance to the ground, the high wing also simplifies loading and unloading. The designed aircraft is a low subsonic airplane, the sweepback angle is related to the speed of airplane, the Mach number of my designed plane is about 0.42 (according to the prototype), so the sweepback angle of my design plane will be quite small, the geometry date of my designed plane will base on the prototype.

There is a main spar and a rear spar in the wing, the spar withstands most bending and torsion load, the two spars create a closed-cell structure which is called torsion box to store fuel tank and carry the torsion and shear load. The wing is covered by aluminum sheet which is called skin, the skin forms the shape of the wing, and it could resist shear and torsion load. Some stringers are attached on the skin in horizontal direction to withstand bending load and prevent skin integrity from bulking. Several ribs are attached on the skin and spar in transverse direction to maintain the aerodynamic shape, distribute concentrated load into structure and also prevent skin integrity from bulking.

The aileron is a second control surface which located at the trailing edge of the wing symmetrically each side. The aileron helps to the lateral control of aircraft. Many things must be considered while design an aileron, such as its hinge moment, and its geometry. Usually, an aircraft structure trim tab will mount on the ailerons, the trim tab is a small movable section to keep balance while the plane in rolling. The right aileron upward deflection angle is 24° and the downward deflection angle is about 16° [1].

The high lift device in my designed plane are flaps. It has similar airfoil shape to the wing, it usually located between the fuselage and the airelon. During take-off and landing, the downward deflection of the flap is about 20 degrees. The structure of the high lift device is similar to the wing. The geometry calculation of flap is quite important because during landing and takeoff, a large and additional lift should be generated by the high lift device to reduce the distance and speed.

The wing design must follow such requirement [1]:

- High aircraft performance requirement;
- good stability during flight requirement;
- producibility requirement;
- operational requirement;
- low-cost requirement;
- flight safety requirement.

Tail unit structure. The tail unit structure consists of the horizontail tail and the vertical tail. The tail unit structure provides the stability and trimming fuction of the aircraft and gives the possibility of control the pitching and yawing movement during flight. The horizontail tail consists of horizontal stabilizer and the elevator which could control the pitch movement of the aircraft and provides the longitudinal stability. The vertical tail consists of rudder and fin which could control the yawing movement of the aircraft and provides the directional stability.

The structure of tail unit is similar to the wing structure, the skin forms the shape of the tail unit, and it could resist shear and torsion load, there is a main spar and a rear spar in the stabilizer to withstand most bending and torsion load. Some stringers are fastened to the skin to withstand bending load and provide skin integrity and prevent bulking, some ribs are glued on the skin to maintain the aerodynamic shape together with stringers.

T-tail structure will be applied on my designed plane, this configuration will provide high aerodynamics performance and excellent glide ratio because the structure is less affected by wing and fuselage slipstream. The T-tail structure will also provide smooth airflow which could reduce friction during flight.

The designed aircraft will use adjustable tail because the adjustable tail allows pilot to control the setting angle for long time during flight operation or before flight as well as the adjustable tail provides more controllable and maneuverable characteristic than the fixed tail [1].

The tail unit design must follow such requirement:

- High aircraft Performance requirement;
- good stability during flight requirement;
- good controllability during flight requirement;
- operational requirement;
- flight safety requirement.

Propulsion system. The primary function of an aircraft engine is to generate adequate thrust to overcome drag during flight and generate adequate flow rate on the wing to provide lift during flight. The secondly function of an aircraft engine is to provide power to subsystem such as anti-icing system, external oil system, hydraulic system, electric system, air conditioning system and fire extinguishing system.

Following requirement must be satisfied to choose engine:

- Sufficient power;
- less fuel cost;
- suitable dimension and weight;
- high fuel efficiency;
- good stability;
- high reliability;
- less noise;
- good maintainability.

The designed aircraft is powered by two PW127M turboprop engines which is localed beneath the wing on each side. And it could supply power reach to 1847KW for each engine [6].

An auxiliary power unit (APU) will be installed in the tail part of the fuselage, the purpose of APU is to provide power to start the engine, produce electric energy to other system and provide necessary thrust in case of engine failure.

Landing Gear. The primary functions of a landing gear are keeping stability during loading unloading while on the ground; make the safe clearance on the ground to prevent ground contact; to absorb the shocking during landing and allow the aircraft taxing on the ground [1].

The type of designed landing gear is tricycle type, it is the case with most of the shortrange plane, it has a single nose wheel in the front of fuselage, and two wheels slightly after of the center of gravity and both wheels have a similar size. I will choose the retractable landing gear system; such system will reduce high drag during flight. This kind of aircraft can land and take-off in any kinds of airport.

To design a satisfied aircraft, next requirement must follow [1]:

- Ground clearance requirement;
- steering requirement;
- low cost and low weight;
- aircraft structural integrity;
- ground lateral stability.

The tricycle-type landing gear consists of many mechanical structure parts. Which include [7]:

- Tire. The tire supports the aircraft on the ground and help to absorb the shock during landing.
- Shock Absorber. It helps to absorb the shock during landing. It consists of stroke, orifices, outer and inner cylinder, and internal spring.
- Strut. It is to withstand main load of the aircraft.
- Steering subsystem. The steering mechanism is connected to the rudder pedal to maneuvers on the ground.
- Retraction System. Include a mechanism to withdraw the landing gear.

Flight Control System. Aircraft flight control systems could be divided into two subsystem which is primary and secondary control systems. The control of the aileron, rudder, and elevator belong to the primary control system. The movement of the flap, spoiler, and the trim is the function of secondary control system.

The designed aircraft has a hydro-mechanical flight control system, it uses hydro-mechanical strength instead of muscular strength. Hydraulical control system will be more powerful to control the surfaces.

The hydro-mechanical flight control system consists of mechanical and hydraulic parts. Generally, the flight control system is mechanically control and hydraulically active. The mechanical system consists of rod, pulley, chain, lever and so on. The hydraulic system consists of actuator, pump, pipes, reservoirs and many different kinds of valves.

The pilot inputs a control signal to the control rod and the control signal will open the servo valve in the hydralic system through the mechanical linkage; the hydraulic system will transfer the power to the actuator and then the control surface; the servo valve will be closed after the actuator move by the so-called mechanical feedback linkage [12]. The control surface will be at the desire position after the feedback opration.

1.2. Geometry calculations for the main parts of the aircraft

1.2.1. Wing geometry calculation

The purpose of this step is to design geometry of the wing as well as the geometry calculation for the main part of the wing which including aileron and high lift device.

Following values will be determined according to the initial date.

initial date for calculation:

- Aspect ratio: λ=12;
- taper ratio: η = 2;
- sweep back angle: χ = 3;
- maximum takeoff weight: m_0=32785 Kg;
- relative load (wing loading) on the wing: p_0=3257 Pa.

As a preliminary estimate, based on the relative load on the wing, the wing area are:

$$S_w = \frac{m_0 g}{p_0} = \frac{32758*9.8}{3257} = 100.7(m^2).$$

Compare the result to the prototype, we took the wing aera as $60m^2$, so:

$$S_w = 60(m^2).$$

The wing span can be figured out:

$$L = \sqrt{S_w * \lambda} = \sqrt{60 * 12} = 26 \text{ (m)}.$$

Chord root:

$$b_0 = \frac{2S_w \eta}{(1+\eta)*L} = \frac{2*60*2}{(1+2)*26} = 3.1\text{(m)}.$$

Chord tip:

$$b_t = \frac{b_0}{\eta} = \frac{3.1}{2} = 1.55\text{(m)}.$$

Root chord is:

$$b_{ob} = b_0 \cdot \left(1 - \frac{(\eta_w - 1)\cdot D_f}{\eta_w \cdot l_w}\right) = 3.1 * \left(1 - \frac{(2-1)\cdot 2.57}{2\cdot 26}\right) = 2.95 \text{ (m)}.$$

where D_f is diameter of fuselage.

Components of design structure is shown in fig 1.3

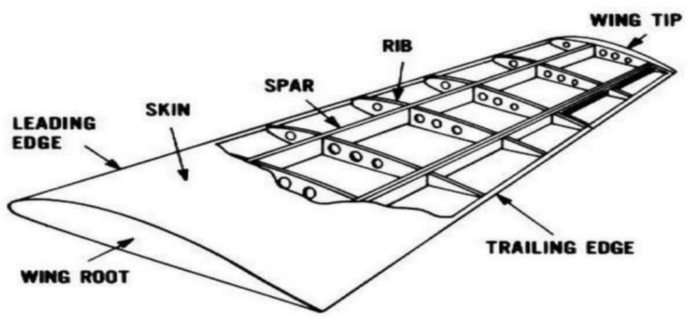


Fig 1.3 - Component of the wing design structure [1]

I use the geometrical method to determine the mean aerodynamic chord (fig 1.4).

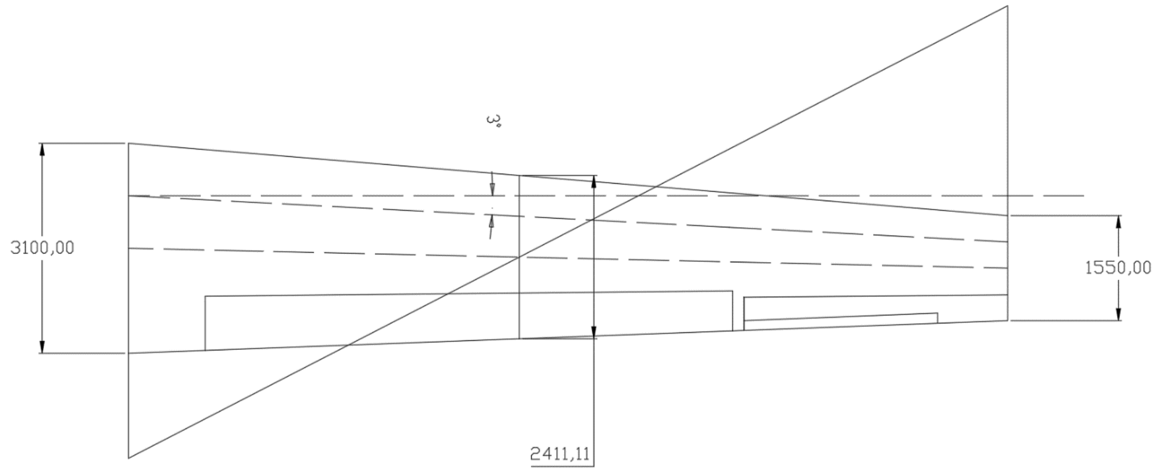


Fig 1.4 - Wing mean aerodynamic chord

Mean aerodynamic chord is equal:

$$b_{MAC}=2.41\text{m}.$$

After determining the geometry of the wing, next is the calculation of the geometry of the ailerons and high-lift devices.

Following parameters must be calculated through the designation of the aileron, the aileron span, aileron area, aileron chord as well as its deflection. The main design requirements for aileron design stem from the controllability of the aircraft roll. The require rolling moment and the distance to the aircraft fuselage center line could affect aileron effectiveness.

Aileron span:

$$l_{ail}=0.3*\frac{L}{2}=0.3*\frac{26}{2}=3.9(\text{m}).$$

Aileron area:

$$S_{ail}=0.065*\frac{S_W}{2}=0.065*\frac{60}{2}=1.95(\text{m}^2).$$

Aileron chord on the right side:

$$b_{ail}=0.24*b_i=0.24*1.55=0.38(m).$$

where b_i is the current chord of the wing which is the chord tip.

Aileron chord on the left side:

$$b_{ail}=0.24*b_i=0.24*2.02=0.49(m).$$

where b_i is the current chord of the wing, we could estimate it from the wing drawing. In this case b_i=2.02m.

Area of ailerons trim tab:

$$S_{tt} = 0.05*S_{ail}=0.05*1.95=0.0975(m^2).$$

I will estimate the deflection angles of differential ailerons according to the prototype:

Upward $\gamma'_{ail}=30°$;

downward $\gamma''_{ail}=20°$.

For the designed aircraft, the high lift devices are flaps, now we come to the calculation of flaps geometry.

The main design requirements for aileron design stem from the ability of increasing of the lift coefficient during take-off and landing. The three main parameters should be determined during flap design are: flap chord, flap span, and flap deflection (up and down). The flap chord must not be so high due to the increment of drag and require high manual power for pilot to move the flap. The flap chord also must not be so low due to the insufficient lift force. So, an appropriate calculation must be proformed.

Flap span:

$$l_{flap}=0.6*\frac{L}{2}=0.6*\frac{26}{2}=7.8(\text{m}).$$

Flap chord on the left side:

$$b_{flap}=0.29*b_i=0.29*2.96=0.86(\text{m}).$$

where b_i is the current chord of the wing which is equal to 2.96 m.

Flap chord on the right:

$$b_{flap}=0.29*b_i=0.29*2.03=0.59(\text{m}).$$

Where b_i is the current chord of the wing, we could estimate it from the wing drawing. In this case b_i=2.03m.

Flap deflection is 20 deg during take-off and 50 deg during landing.

1.2.2. Fuselage layout

In this part we come to deal with the fuselage layout, we will calculate and design the geometry of nose part, baggage compartment, passenger compartment, and tail part. The work is to provide enough space for aircraft furniture in the cockpit, convenient location of the flight control instrument and comfort for passenger.

In my designed plane, the fuselage divided into four parts, nose part, cargo compartment, passenger cabin and tail part, the pilot cab is in the nose part, galley and toilet are in the tail part, the two flight attendance seats both install in the cargo part and tail part which is near the passenger cabin.

Following initial date will be determined according to the prototype aircraft.

Initial date for calculation:

- Fuselage diameter D_f=2.57m;
- fuselage fineness ratio λ_f =10.57;
- fuselage nose part fineness ratio λ_{np} =2.34;
- tail unit fineness ratio λ_{TU} =2.66.

Calculation:

Length of fuselage:

$$l_f=\lambda_f * D_f=10.57*2.57=27.17(m).$$

Length of the nose part:

$$l_{nose}=\lambda_{np} * D_f=2.34*2.57=6.02(m).$$

Length of the tail unit:

$$l_{tu}=\lambda_{TU} * D_f=2.66*2.57=6.84(m).$$

In the designed aircraft, passenger number is 68, the layout of the passenger seat is 2*2 for one row and 17 rows in total.

The width of passenger cabin:

$$B_{cabin}=2a+n_{block}*b_{block}+n_{aisle}*b_{aisle}=2*67.76+2*867.34+1*539.83=2.41(m).$$

Where a is the distance between the arm to the fuselage, n_{block} is amount of chair block, b_{block} is the width of one chair block, n_{aisle} is the amount of aisle, b_{aisle} is the width of aisle.

The length of passenger cabin:

$$L_{cab}=L_1+(n_{row}-1)*L_{seatpitch}+L_2=884.47+(17-1)*820+313.37=14.31(m).$$

where L_1 is the clearance of front passenger cabin, L_2 is the clearance of tail passenger cabin, $L_{seatpitch}$ is the distance between forward chair and afterward chair.

In my designed plane, the aisle height is 1.97m, the distance from the window to the flour is 1.14m(according to prototype).

There are 27 windows on each side of passenger cabin, the shape of the window is rectangular with the rounded corners. The distance between two windows is corresponds to frame step which is equal to 0.5m.

1.2.3. Luggage compartment

In this step, we come to calculate the area and volume of cargo compartment.

According to the prototype, the area road of the floor is K=500 kg/m^2. 25kg baggage, 15kg cargo and mail will be taken for one passenger, volume of cargo for each passenger will be approximately 0.2m^3.

The area of cargo compartment is defined:

$$S_{cargo}=\frac{M_{bag}}{0.4K}+\frac{M_{cargo\&mail}}{0.6K}=\frac{25*68}{0.4*500}+\frac{15*68}{0.6*500}=11.9\ (m^2).$$

Cargo compartment volume is equal:

$$V_{cargo}=v*n_{pass}=0.2*68=34(m^3).$$

1.2.4. Galleys and buffets

In this step, we will calculate the area and volume of galleys.

Volume of galleys is equal:

$$V_{galley}=0.1*68=6.8(m^3),$$

Area of galleys is equal:

$$S_{galley}=\frac{V_{galley}}{H_{cab}}=\frac{6.8}{1.97}=3.45(m^2).$$

1.2.5. Lavatories

In this step, we come to calculate the area and quantity of lavatories in designed aircraft, Toilet design is similar to the prototype.

Time in flight

$$T=\frac{\text{flight range}}{\text{cruise speed}}+0.5=\frac{1528}{510}+0.5=3.5(h).$$

So, we take one toilet for 50 passengers, then number of lavatories are:

$$n_{lav}=2.$$

Area of lavatory:

$$S_{lav}=1.5\ (m^2).$$

1.2.6. Tail unit geometry calculation.

In this step we come to determine geometrical parameters of the tail unit. The difference between the the wing design and tail unit design is the main function of wing is to generate the lift force while the main function of the tail unit is maneuver.

T-tail structure will be applied in our designed plane, It could be divided into two parts: the horizontal tail and the vertical tail.

The following parameters have been found:

L_{VTU}: arm of vertical tail unit equal to 10.28m.

L_{HTU}: arm of horizontal tail unit equal to 10.28m.

A_{VTU}: statistic coefficient, in this case equal to 0.085.

A_{HTU}: statistic coefficient, in this case equal to 0.75.

Calculation:

Area of vertical tail unit is equal:

$$S_{VTU} = \frac{l_w * S_w}{L_{VTU}} * A_{VTU} = \frac{26*60}{10.28} * 0.085 = 12.9 (m^2).$$

Area of horizontal tail unit is equal:

$$S_{HTU} = \frac{b_{MAC} * S_w}{L_{HTU}} * A_{HTU} = \frac{2.41*60}{10.28} * 0.75 = 10.55 (m^2).$$

Determination of the elevator and rudder area:

Elevator area:

$$S_{el} = 0.35 * S_{HTU} = 0.35 * 10.55 = 3.7 (m^2).$$

Rudder area:

$$S_{ru} = 0.4 * S_{VTU} = 0.4 * 12.9 = 5.16 (m^2).$$

Elevator balance area is equal:

$$S_{eb} = 0.26 * S_{HTU} = 0.26 * 10.55 = 2.7 (m^2).$$

Rudder balance area is equal:

$$S_{rb}=0.22*\ S_{VTU}=0.22*12.9=2.84(m^2).$$

The area of the elevator trim tab:

$$S_{te}=0.08*S_{el}=0.08*3.7=0.3(m^2).$$

Area of rudder trim tab is equal:

$$S_{tr}=0.06*S_{ru}=0.06*5.16=0.31(m^2).$$

According to the prototype, we accept:

- Taper ratio of HTU: $\eta_{HTU}=1.43$;
- length of HTU: $l_{HTU}=2.57*3.37=8.3$ (m);
- taper ratio of VTU: $\eta_{VTU}=1.95$;
- length of VTU: $l_{VTU}=2.57*1.75=4.5$ (m).

Root chord of horizontal stabilizer is:

$$b_{0HTU}=\frac{2*S_{HTU}*\eta_{HTU}}{\left(1+\eta_{HTU}\right)*L_{HTU}}=\frac{2*10.55*1.43}{(1+1.43)*8.3}=1.5(m).$$

Tip chord of horizontal stabilizer is:

$$B_{tHTU}=\frac{b_{0HTU}}{\eta_{HTU}}=\frac{1.5}{1.43}=1.05(m).$$

Root chord of vertical stabilizer is:

$$b_{0VTU}=\frac{2*s_{VTU}*\eta_{VTU}}{(1+\eta_{VTU})*L_{VTU}}=\frac{2*12.9*1.95}{(1+1.95)*4.5}=3.63(m).$$

Tip chord of vertical stabilizer is:

$$B_{tVTU}=\frac{b_{0VTU}}{\eta_{VTU}}=\frac{3.63}{1.95}=1.86(m).$$

1.2.7. Landing gear design

In this step, we will design the geometry of landing gear and calculate the load per wheel. Then choose the proper tire in each wheel.

My designed aircraft is a tricycle type, one landing gear in the nose part, and two landing gears is in the fuselage, each landing gear has two wheels. there are all retractable.

Distance between the rear landing gear and central of gravity (Main wheel axel offset):

$$e=0.17*b_{mac}=0.17*2.41=0.40\ (m).$$

length of landing gear wheel base:

$$B=0.4*L_f=0.4*27.17=11.03\ (m).$$

Distance between the front landing gear and central of gravity (Front wheel axial offset):

$$D_{ng}=B-e=11.03-0.4=10.63\ (m).$$

Wheel track is:

T=0.32*11.03=3.6 (m).

Then come to calculate the load on the wheel.

Nose wheel load is equal:

$$P_{NLG}=\frac{9.81*e*k_g*m_0}{(B*Z)}=\frac{9.81*0.4*1.7*32785}{11.03*2}=9914\ (N).$$

where K_g is dynamics coefficient which is equal 1.7

Main wheel load is equal:

$$P_{NLG}=\frac{9.81*(B-e)*m_0}{(B*Z*n)}=\frac{9.81*(11.03-0.4)*32785}{11.03*2*2}=77489\ (N).$$

According to the load in the wheel, then I will choose the tire for nose wheel and main wheel. choose the tire must follow next requirement:

$$P^K_{slmain} \geq P_{main};P^K_{s\ln ose} \geq P_{nose};V^K_{landing} \geq V_{landing};V^K_{takeoff} \geq V_{takeoff}$$

Such tires are suitable for my design plane which is shown in Table 1.3.

Table 1.3 - Aviation tires for prototype

Main gear				Nose gear			
Tire size	Ply rating	Speed	Type	Tire size	Ply rating	Speed	Type
720*250mm	14	190km/h	radial	450*190mm	10	190km/h	bias

1.2.8. Choice and description of power plant

I will choose the engine according to my prototype aircraft. The design aircraft is powered by two PW127M turboprop engines which is localed beneath the wing on each side. And it could supply power reach to 1847KW for each engine. The characteristics of the choosen engine is shown on table 1.4.

Table 1.4 - Characteristic of PW127M turboprop engine:

Series	Thermo. ESHP	Mech. SHP	Prop.max. RPM	Height	Width	Length
PW127 turboprop engine	3,200	2,750	1,200	33 in	26 in	84 in

1.3. Determination of the aircraft center of gravity positions

An aircraft is made up by many different components, such as fuselage, wing engine, landing gear and payload; they have own masses and centers of gravity, so we must determine thier distributions along the aircraft to get a safe center of gravity range. In this part I will determine the center of equipped wing and the center of equipped fuselage, combine the wing center and the fuselage center together and finilly get the center of gravity of the designed aircraft.

1.3.1. Determine the center of the equipped wing

In this part we come to determine the center of the equipped wing. The list of mass objects in the wing with engines are shown in table 1.5. The axis X is the horizontal line start from leading edge of MAC and the coordinates of the center of the equipped wing which is determined by the formula:

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

Table 1.5 - Trim sheet of equipped wing

N	object name	Mass		Coordinates, m	MTM
		units	total mass, kg		Mass moment, Kg.m
1	wing (structure)	0.13087	4290.57	1.04	4446.32
2	fuel system	0.0039	127.86	1.03	132.50
3	airplane control, 30%	0.00261	85.57	1.45	123.73
4	electrical equipment, 30%	0.00657	215.40	0.24	51.91
5	anti-ice system, 70%	0.01638	537.02	0.24	129.42
6	hydraulic systems, 70%	0.01533	502.59	1.45	726.75
7	power plant	0.14561	4773.82	0.30	1432.14
8	equipped wing without fuel	0.32127	10532.84	0.67	7042.79
9	fuel	0.13601	4459.09	1.04	4620.95
	total	0.45728	14991.92	0.78	11663.73

1.3.2. Determination of the centering of the equipped fuselage

In this part we come to determine the center of the equipped fuselage. The list of mass objects in the fuselage with landing gears are shown in table 1.6. The axis X is the horizontal center line of the fuselage and the point of front nose will be the coordinate origin. The coordinates of the fuselage centering are determined by the formula:

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

Table 1.6 - Trim sheet of equipped fuselage

N	objects names	Mass		C.G coordinates, m	mass moment, kg.m
		units	total mass, kg		
1	fuselage	0.11475	3762.06	13.50	50788.06
2	horizontal tail	0.01705	558.99	26.00	14533.59
3	vertical tail	0.01948	638.65	26.00	16604.95
4	radar	0.0044	144.25	0.50	72.13
5	radio equipment	0.0024	78.68	0.80	62.95
6	instrument panel	0.0077	252.44	2.00	504.89
7	aero navigation equipment	0.0066	216.38	1.80	389.46
8	lavatory2, galley 1	0.0098	321.29	22.00	7068.45
9	lavatory2, galley 2	0	0	0	0
10	aircraft control system 70%	0.00609	199.66	13.60	2715.38
11	hydro-pneumatic sys 30%	0.00648	212.45	13.00	2761.81
12	electrical equipment 70%	0.02093	686.19	10.00	6861.90
13	not typical equipment	0.0015	49.18	10.00	491.78
14	furnishing and thermal equipment	0.0086	281.95	10.00	2819.51
15	anti ice and airconditioning system	0.00702	230.15	10.00	2301.51
16	passenger seats	0.02	655.70	13.50	8851.95
17	seats of flight attendence1	0.00074	24.26	21.00	509.48
18	seats of flight attendence2	0.00074	24.26	5.67	137.56
19	seats of pilot	0.00047	15.41	2.50	38.52
20	additional equipment	0.00153	50.16	10.00	501.61

Ending of table 1.6 - Trim sheet of equipped fuselage

21	nose landing gear	0.00721	236.38	2.50	590.95
22	Main landing gear	0.04086	1339.60	13.50	18084.53
	equipped fuel without payload	0.30435	9978.11	13.70	136690.99
	equipped fuel without payload and landing gear	0.25628	8402.14	14.06	118015.50
24	on board meal	0.0018	43.40	22.00	954.80
25	baggage	0.052	1700.00	7.60	12920.00
26	cargo, mail	0.031	1020.00	7.60	7752.00
27	crew	0.0086	280.00	8.50	2380.00
28	Passengers(economy)	0.145	4760.00	15.50	73780.00
	TOTAL	0.54275	17781.51	13.19	234477.79
	TOTAL fraction	1.00003			

After determining the CG of fully equipped wing and fuselage, then we come to determine the wing MAC leading edge position relative to fuselage, value of X_{MAC} is determined by formula:

$$X_{MAC} = \frac{m_f x_f + m_w \cdot x_w - m_0 C}{m_0 - m_w} = \frac{18370+225784-32785*2.352*0.23}{32785-14991} = 12.8\ (m).$$

where m_0 is aircraft takeoff mass, kg; m_f is mass of fully equipped fuselage, kg; m_w is mass of fully equipped wing, kg; C is distance from MAC leading edge to the C.G. point, which is equal to 0.23 [1].

1.3.3. Calculation of center of gravity positioning variants

Based on above calculation, I have determined CG positioning variants and airplanes center of gravity position variants and shown on the table 1.7 and table 1.8.

Table 1.7 - Calculation of C.G. positioning variants

Name	Mass	Coordinate	Mass moment
Object	Kg	m	Kg.m
equipped wing (without fuel and landing gear)	10532.84	13.10	137959.10
nose landing gear (extended)	236.38	2.50	590.95
main landing gear (extended)	1339.60	13.50	18084.53
fuel/fuel reserve	4459.09	13.10	58405.13
equipped fuselage (without payload and landing gear)	8412.04	14.05	118155.51
passengers of economy class	4760.00	15.50	73780.00
baggage	1700.00	7.90	13430.00
cargo	1020.00	7.90	8058.00
crew	280.00	8.50	2380.00
nose landing gear (retracted)	236.38	1.60	378.21
main landing gear (retracted)	1339.60	13.50	18084.53
reserve fuel	1325.50	14.00	18556.97

Table 1.8 - Airplanes center of gravity position variants

No.	Variants of the loading	Mass, kg	Moment of the mass, kg.m	Center of mass, m	Centering
1	take off mass (L.G. extended)	32785	430843.22	13.14	0.18
2	take off mass (L.G. retracted)	32785	430630.48	13.13	0.18
3	landing weight (LG extended)	29606.35	390995.06	13.21	0.21
4	ferry version	25259.94	335362.48	13.28	0.25
5	parking version	20520.85	274790.10	13.39	0.29

1.4. Conclusion to the first part:

During the firt part of project, I have got the result of preliminary design of the short-range passenger aircraft with 68 passenger capacity which includes:

- Brief description of the main parts in the designed aircraft;
- geometry for the main parts of the designed aircraft;
- furniture layout in the designed aircraft;
- position of the engine;
- aircraft center of gravity position;
- configuration of landing gear.

The designed airplane will provide great passenger comfort during flight due to its reasonable layout, good in-flight service, adequate entertainment, convenient service facilities, and smooth experience.

The proposal of the preliminary design of the aircraft is feasible because it strictly follow the requirement of FAR-25, CS-25 and CCAR-25.

PART 2. CONVEYOR BELT DESIGN

2.1. Background

Nowadays, aircraft loading and unloading systems are a rather important part of airline service. For some big airlines and their large aircraft, the handling system is very complete and comprehensive, but for some small airlines and small aircraft, the handling system is often not comprehensive. In the case of the prototype aircraft ATR-72, due to the imperfect facilities at the airport, its baggage was transported by trolley and loading and unloading by manpower, which not only consumed a lot of manpower and financial resources, but also has a very low loading and unloading efficiency. Based on this phenomenon, I decided to design a conveyor belt which could mounted on the cargo door for loading and unloading passengers' baggage, and this conveyor belt could work with the opening of the cargo door. This conveyor belt will greatly save manpower and increase the efficiency during loading and unloading.

The purpose of the work is preliminary design of the conveyor belt which is installed on the cargo door for loading and unloading passenger baggage.

To gain this aim the following tasks have been solved:

- The main requirements for conveyor belt;
- brief description of the main parts of the conveyor belt;
- layout of the conveyor belt;
- geometry and strength calculations for the main parts of the conveyor belt;
- selection of the electrical motor and pulleys for conveyor belt.

2.2. Analysis and selection of existing conveyor belts

The conveyor belt is used to move the position of the material from start to finish position. It could usually significantly improve the efficiency of the work when the material has lots of back and forth between the two position and the route of the material movement is fixed.

Generally, the conveyor belt could be classified by following ways:

- Type of load the conveyor will withstand: unit load or bulk load;
- placement of the conveyor belt: overhead, on-floor, or in-floor;
- whether the load can be accumulated on the conveyor.

The objective of this work is preliminary design of the convery belt, so I will compare five types of conveyor belt and choose one prototype which is suitabe for my design conveyor belt. General characteristic of prototypes presented in table 2.1.

Table 2.1 – General characteristic of different type of conveyor belt [13].

Type of conveyor belt	Type of handle	Type of placement	Whether accumulate	Characteristics of conveyor belt
Chute Conveyor	Unit/Bulk	On-Floor	Accumulate	It usually used to convey material between two floors, the cost of such conveyor belt is not too expensive but it is quite difficult to control the movement of the material in the belt.
Flat Belt Conveyor	Unit	On-Floor	Not accumulate	It usually used to convey medium weight material between two buildings and two flow line, there will be no smooth stacking, merging and sorting on the belt. The roller or slider bed will support the belt to convey items

Ending of table 2.1 - General characteristic of different type of conveyor belt.

Magnetic Belt Conveyor	Bulk	On-Floor	-	The magnetic pulley or magnetic slider bed will support the magnetic belt to convey items. It is used to convey ferrous materials in vertically and upside down position
Troughed Belt Conveyor	Bulk/Unit	On-Floor	-	When loading the material, The belt will be dented，which leads to the same shape as the idler pulley, It will prevent the material from sliding away and improve the stability of the transmission.
Modular Belt Conveyors	Bulk/Unit	On-Floor	Not accumulate	These systems use belts that consist of hard plastic segments. These segments are individual, interlocking. It is easy to repair and wash.

The object of my work is to design a conveyor belt which is installed on the cargo door for loading and unloading passenger baggage. After comparing these conveyor belt above I choose to design the Troughed Conveyor Belt type, because it has following advantages than others:

- It will prevent the material from sliding away and improve the stability during conveying;
- it can withstand high weight items such as passengers' luggage;
- it has high reliability than other conveyor belts;
- good energetic efficiency;
- it has a low weight structure;
- it can be incline to convey items and it could satisfy my requirement;
- it has a high structure strength due to its connection method of each component.

2.3. Definition of the problem

The main problem is the strength calculations for the main parts of the conveyor belt (fig.2.1) as well as design the geometry and choose the suitable structural materials which could satisfy the strength requirement.

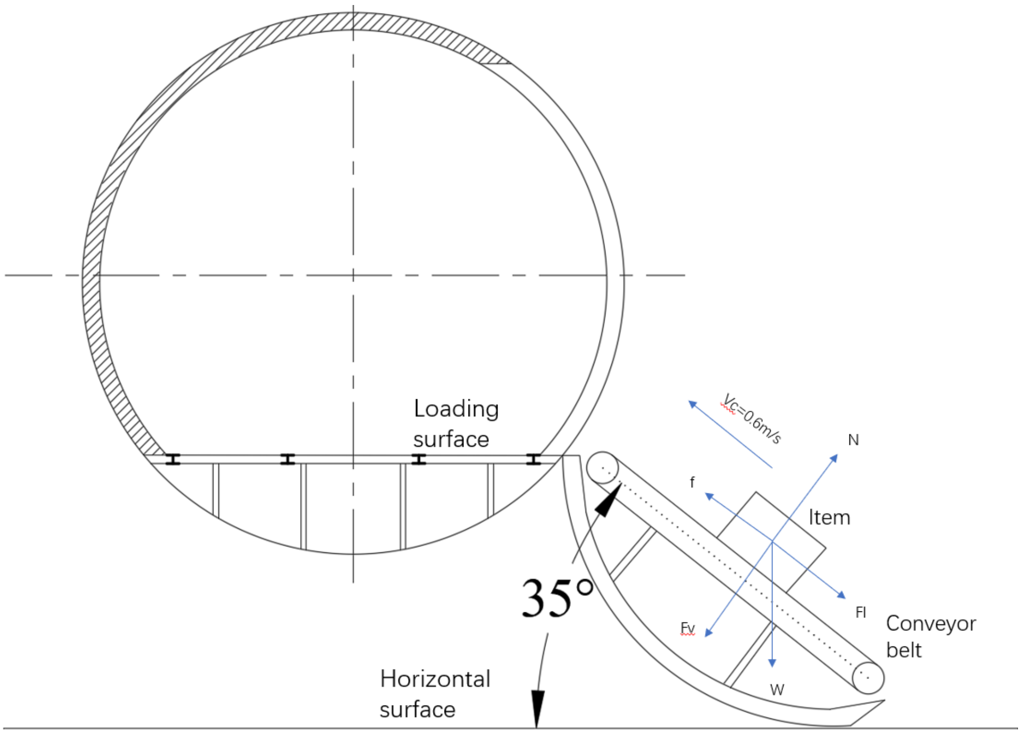


Fig.2.1 – Conveyor scheme

The aim of the conveyor belt is to move the passenger baggage from the horizontal ground surface to the loading surface, the main principle of this work is shown above. The slope angle of the convey belt is α: 35°. The convey belt will be installed on the cargo door so the geometry of the convey belt will correspond to the geometry of the cargo door which means the length of the convey belt is equal to L_b: 1.6 m and the width is equal to w_b: 0.6m. the weight of one passenger baggage is approximately equal to W: 25kg.

2.4. Brief description of the main parts of the designed conveyor belt.

The belt consists of two pulleys and the belt is wound to the two pulleys to transport items. The main pulley is powered by an electric motor and it is also called as the drive pulley, another pulley does not have any power supply and its function is to change the direction of the belt so that it could become a closed loop, this pulley is called the tail pulley. The belt is wrapped around these two pulleys and is sunken downwards to form the shape of idlers [3]. The belt is supported by several idlers which withstand the main forces exerted on the belt by the items and it also form the general shape of the conveyor belt. In order to keep the conveyor system running properly, the belt must always be stressed and a return idler is a good solution to this problem. The belt must contain scrappers for belt cleaning to prevent wear of the belts, idlers and pulleys [3]. A drive system will in the head part of the conveyor belt to provide power for the drive pulley, the drive system is consist of motor, coupling and gearbox.

Belt. The belt is considered to be the most important part of the conveyor belt, which not only transports the load, but also absorbs the energy of the impact at the loading point. The belt must not only meet the requirements of strength, but also withstand the effects of ambient temperature and corrosive substances, and meet the safety requirements of fire and static resistance. A belt usually consists of two parts： the carcass and the cover.

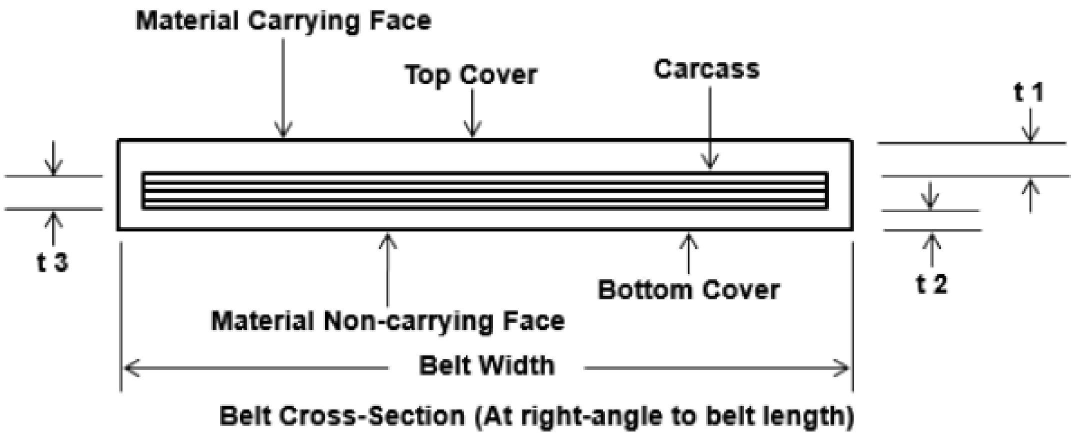


Fig.2.2 - Belt part [3]

The carcass in the conveyor belt will satisfy following requirement:

- Provides sufficient tensile strength to support and move items;
- absorbs the energy of the impact at the loading point;
- to provide both lateral and longitudinal stiffness for the movement of items on idlers.

The function of the cover is to protect the internal material from chemical corrosion, and abrasion, and it also could be a shock absorber to absorber part of the impact energy. The material used for the cover is usually rubber and PVC [3]. The surface of the cover is quite rough to provide the friction for the movement of the items.

Idle. Due to the distance between the drive pulley and the tail pulley are too far and it should satisfy the strength requirement, There must be something between the two pulleys to support the belt and because the belt is moving considering the need to reduce friction, so the rollers which is called idlers are necessary to install between the two pulleys to support the belt and the presence of these idles can effectively prevent the item from move side to side. An idler set is composed of an idler frame and roller. the main functions of the idler are [3]:

- Support the movement of the belt;
- minimize friction during the movement of the belt and the item;
- contouring of belt grooves for better retention of items;
- the idler reduces the pressure on the roller which is applied by the belt during the transition from flat to groove;
- helps belt self-alignment.

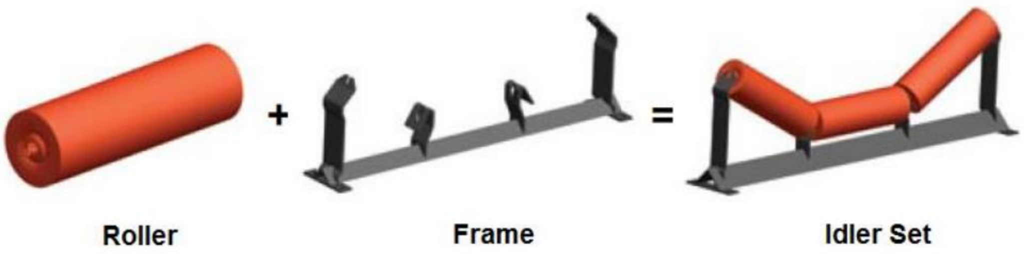


Fig.2.3 - Part of idler [3]

Usually, a roller is consisted of tube, bearing, spindle, sealing and breather hole. These rollers are mounted on the frames which form a fixed idler set. Here is the typical construction of roller:

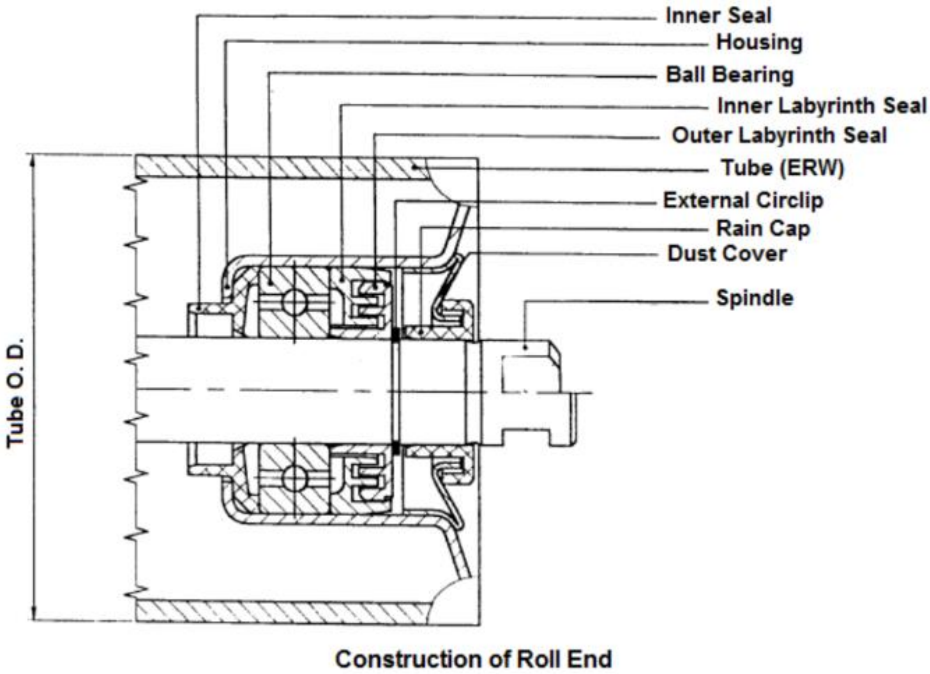


Fig.2.4 - Construction of roller [3]

Pulley. The pulley is one of the most important part of the conveyor, which changes the direction of the belt to form an endless closed loop, transfer energy to the belt and support the belt. the pulley can simply be divided into drive-pulley and non-drive. The pulley can also be classified as: wing pulley, spiral pulley, magnetic pulley [3]. Usually the drive-pulley is at the head of the belt and the non-drive pulley is at the tail of the belt. The key difference between the drive-pulley and non-drive is that the drive-pulley has to withstand the torque force generated by the motor while the non-drive pulley doesn't.

A standard pulley consists of a rim, two hub, two disk, a lagging, two external bearing and on shaft.

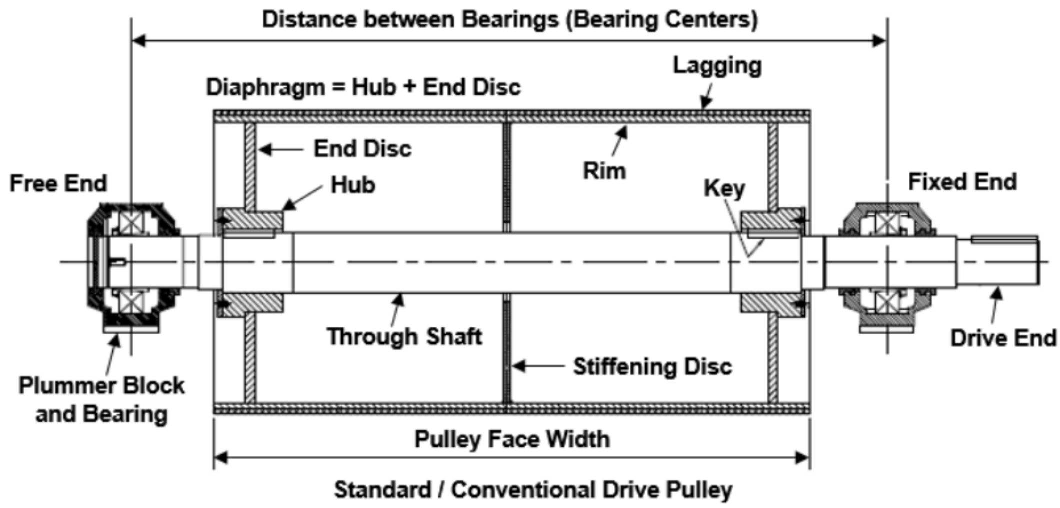


Fig.2.5 - Drawing of standard pulley [3]

Drive units and gearboxes. Generally, a conveyor belt contains one or more drive units, which provide torque moment to the pulley and give energy for the movement of the belt. Generally, a drive unit has the following components: a gear box, an electrical motor, a coupling and a brake.

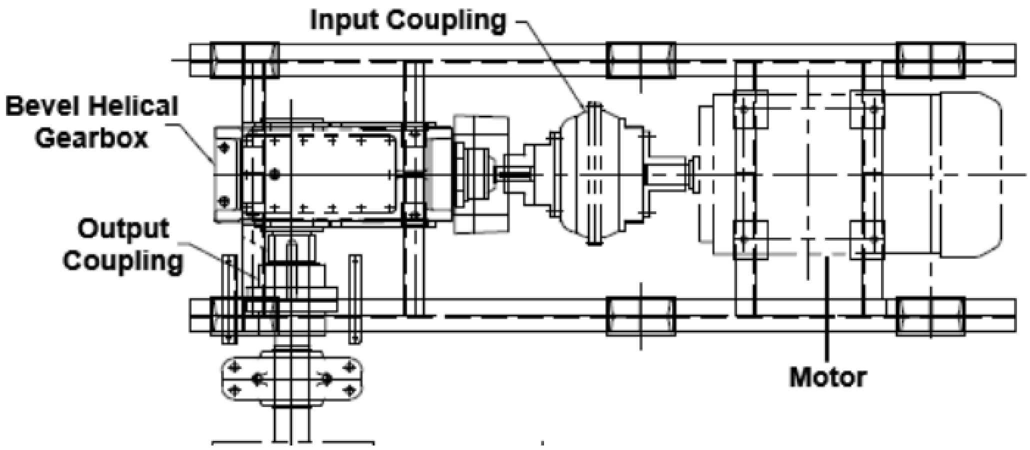


Fig.2.6 - Drawing of drive units and gearbox [3]

The function of gear box is to reduce the input speed due to the desire drive pulley speed is less than the motor speed. Generally the foot mounted worm gear box is wildly used, it has following features [8]:

- The position of input shaft and output shaft are hetero-facial which could save much space for stalling;

- the range of mechanical efficiency of transmission is about 80%-90%;
- it has self-locking feature which could prevent roll back of incline conveyor.

A coupling is used to connect motor output shaft and gearbox input shaft in order to transmit the power. It can be generally classified as rigid coupling and flexible coupling. In most occasions the two shaft is misalignment during rotation so a flexible coupling is necessary to choose to prevent such harmful effect.

Two types of motor are used in the conveyor belt, they are DC motor and the AC motor. Usually, the require starting torque moment is larger than the running torque moment, Actually, the DC motor has high starting torque but it has poor speed and voltage regulation and it can't be run at no load condition. So the 3-phase induction motor will be used in the conveyor belt system.

2.5. Geometry and strength calculations for the main parts of the conveyor belt

2.5.1. Belt selection

Our application requires an adhesive belt to prevent the items slide down due to the big slope. A slide bed which is consist of several rolls will support the belt. The adhesiveness between the load and the belt sample could be test by place one item on the belt and see if the item will slide down.

The material of rubber/polyester will be a good choice for the belt because of its high adhesiveness.

Initial date of the choosen belt:

- Belt thickness, t: 2 mm;
- belt mass, m: 2.7 kg/m^2;
- max. tensile force per length, T_m: 12 N/mm;
- pulley friction coefficient, f_p: 0.25;
- slider bed friction coefficient, f_b: 0.3;
- velocity of conveyor belt: V_c=0.6m/s.

2.5.2. Pulley geometry design

The pulley is one of the most important part of the conveyor, which changes the direction of the belt to form an endless closed loop, transfer energy to the belt and support the belt. Usually, the pulley is standard and sometimes supplied by belt manufacturer. For our application, following pulley (Fig.2.7) is used for the drive and idler end.

Pulley material: UNS G43400 which is a low-alloy Steel with carbon content 0.38-0.43％ and it is wildly used in manufacturing shaft , link components and roller due to its high toughness and strength.

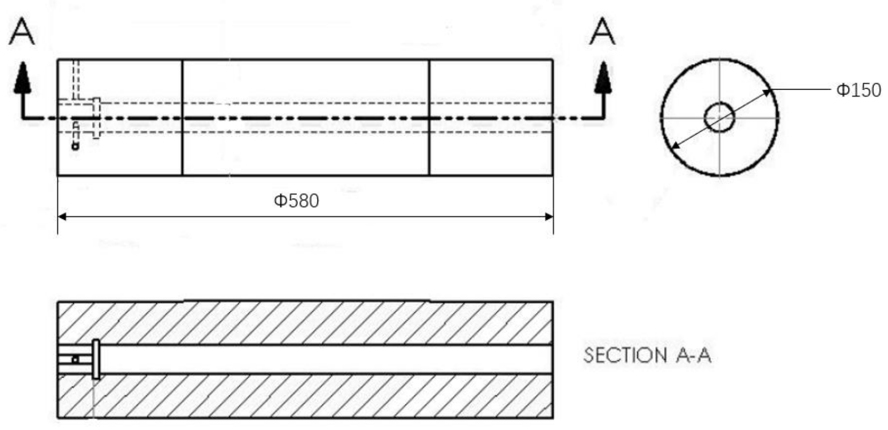


Fig.2.7 - Pulley geometry design [5]

Initial date of the choosen pulley:

- Diameter of Pulley d_p: 150 mm;
- width of pulley, w_p: 580 mm;
- belt wrapping angle, θ: 180°.

2.5.3. Assessment of the torque moment and choose the standard motor

Time to accelerate t_a must be short enough to minimize overload current and to maximize conveyor output, must be long enough to prevent items from slipping. In case t_a= 3 sec.

Speed of pulley:

$$\omega = \frac{v_c}{\frac{d_P}{2}} = \frac{0.6}{\frac{0.15}{2}} = 8 \text{ (rad/sec)}.$$

Acceleration of pulley:

$$a = \frac{\omega}{t_a} = \frac{8}{3} = 2.67 (\text{rad/s}^2).$$

Weight of one pulley:

$$W_P = \frac{(7833 k_g/m^3)*\pi*(d_p^2 - d_i^2)*L_P}{4} = \frac{7833*3.14*(0,15^2 - 0.14^2)*0.58}{4} = 10.3 \text{ (kg)}.$$

Mass inertia of pulleys:

$$J_P = 2*\left(\frac{W_p*d_p^2}{8}\right) = 2*\left(\frac{10.3*0.15^2}{8}\right) = 0.058 \text{ (kg*m}^2\text{)}.$$

Weight of belt:

$$W_b = \frac{m*w_b*(2L_b + \pi*w_p)}{1000} = \frac{2.7*580*(2\times1.6 + 3,14\times0.15)}{1000} = 5.7 \text{ (kg)}.$$

Mass inertia of belt:

$$J_b = \frac{W_b*d_p^2}{4} = \frac{5.7*0,15^2}{4} = 0.032 \text{ (kg*m}^2\text{)}.$$

Mass inertia passenger baggage:

$$J = \frac{W * d_p^2}{4} = \frac{25 * 0{,}15^2}{4} = 0.14(\text{kg*m}^2).$$

We could get the total mass inertia by adding the mass inertia of pulleys, the mass inertia of belt and the mass inertia passenger baggage:

$$J_t = J_P + J_b + J = 0.058 + 0.032 + 0.14 = 0.23\ (\text{kg*m}^2).$$

Torque of acceleration:

$$T_a = J_t * a = 0.23 * 2.67 = 0.61(\text{N*m}).$$

Friction on belt caused by the slider bed:

$$F_s = (W + m * L_b * w_b) * g * f_b * \cos\alpha =$$
$$(25 + 2.7 * 1{,}6 * 0.6) * 9.8 * 0.3 * \cos 35^0 = 66.5(\text{N}).$$

Torque of friction:

$$T_f = \frac{F_s * dp}{2} = \frac{66.5 * 0.15}{2} = 5\ (\text{N*m}).$$

Force requires for item lift:

$$F_1 = W * g * \sin\alpha = 25 * 10 * \sin 35 = 143(\text{N}).$$

Torque requires for item lift:

$$T_1 = \frac{F_1 * dp}{2} = \frac{143 * 0.15}{2} = 10.7 (N*m).$$

We could get the total torque by adding the torque of acceleration. The torque of friction and the torque required for item lift:

$$T_t = T_a + T_f + T_1 = 0.61+5+10.7 = 16.31 (N*m).$$

Determine the require power for the design conveyor belt:

$$P = T_t * \omega = 16.31*8 = 130 \text{ (Watts)}.$$

According to above calculation, I will choose the standard aviation three-phase squirrel cage induction motor which is MOT 443MC17 (it is a standard motor manufactured by 'Western Applied Technologies') and it has following characteristic (table.2.2) which could satisfy my design requirement:

Table.2.2 - Characteristic of choosen aviation motor

Type	Output(kw)	Current (A)	Eff (%)	Speed (r/min)	Tstart/Tn	maximum output torque(N*m)	Packing Size (cm)
200V 400Hz Synchronous Speed 5400 r/min (2 Poles)							
MOT 443MC17	0.56	3	65.0	5400	2.2	19	27.5x22.8x18.5

Gear box ratio:

$$R_g = \frac{\frac{5400}{60}}{w} = \frac{90}{8} = 11.25.$$

2.5.4. Belt strength analysis

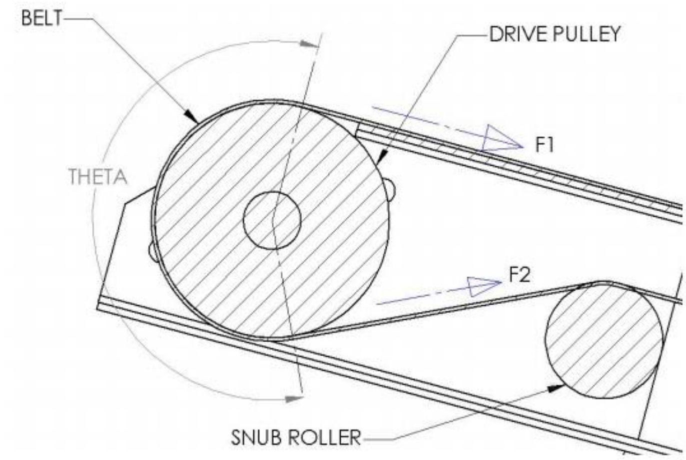


Fig.2.8 - Detail drawing of drive pulley part [5]

Tension force on carrier side：

$$F_1 = \frac{\frac{T_t}{d_P/_2}}{1-\frac{1}{e^{fp*\theta}}}=\frac{\frac{16.31}{0.15/2}}{1-\frac{1}{2.718^{0.25*\frac{\pi}{2}}}}=670（N）.$$

Tension force on carrier side:

$$F_1 = \frac{\frac{T_t}{d_P/_2}}{1-\frac{1}{e^{fp*\theta}}}=\frac{\frac{16.31}{0.15/2}}{1-\frac{1}{2.718^{0.25*\frac{\pi}{2}}}}=670（N）.$$

Tension (return side):

$$F_2 = \frac{F_1}{e^{fp*\theta}}=\frac{670}{2.718^{0.25*\frac{\pi}{2}}}=453（N）.$$

Belt tension force per length:

$$\sigma_b = \frac{F_1}{L_b}=\frac{670}{1600}=0.41 \text{ (N/mm)}.$$

Safety factor of the choosen belt:

$$SF_b = \frac{T_m}{\sigma_b} = \frac{12}{0.41} = 29.$$

According to the calculation of belt safety factor we could conclude that the strength of the selected belt is adequate.

2.5.5 Pulley deflection analysis

Pulley deflection under maximum load.

Inertia of pulley:

$$I_p = \pi \cdot \frac{d_p^4 - d_i^4}{64} = 3.14 * \frac{0.15^4 - 0.14^4}{64} = 6.0*10^{-6}(m^4).$$

Deflection of the pulley:

$$y = \frac{5*(F_1+F_2)*w_p^4}{384*E*I_P} = \frac{5*(670+453)*0.58^4}{384*2.07*10^{11}*6*10^{-6}} = 0.0015(mm).$$

The deflection is quite small so we can draw a conclusion that the pulley have no deflection.

2.5.6. Shaft design

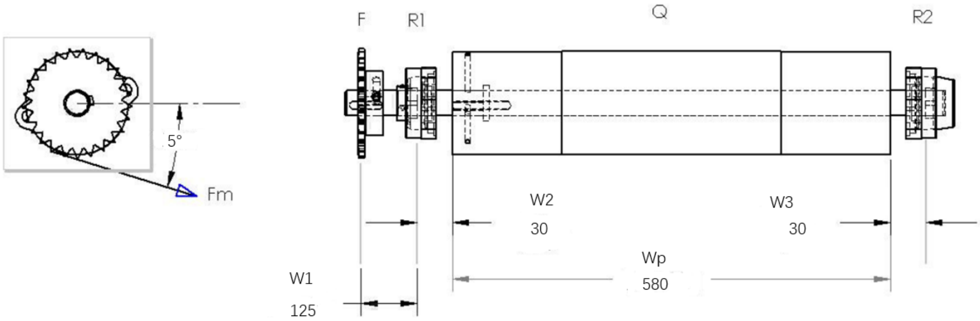


Fig.2.9 - Geometry of drive pulley part [5]

Drive shaft loads.

Input force:

$$F_m = \frac{T_t}{\frac{D_S}{2}} = \frac{16.31}{\frac{0.052}{2}} = 627.3 \text{ (N)},$$

where D_s is diameter of sprocket which is equal 0.052m.

Force along the conveying direction:

$$F_x = F_m * cos\, 5^0 = 627.3 * cos\, 5^0 = 624.9 \text{(N)}.$$

Bending torque along the conveying direction:

$$M_{1x} = -F_x * w_1 = -624.9 * 0.125 = -78.1 \text{(N*m)}.$$

Force along the vertical direction:

$$F_y = F_m * sin\, 5^0 = 627.3 * sin 5^0 = 54.7 \text{(N)}.$$

Bending torque along the vertical direction:

$$M_{1y} = -F_y * w_1 = -54.7 * 0.125 = -6.8 \text{ (N*m)}.$$

Distributed force caused by the belt:

$$Q = \frac{F_1 + F_2}{w_p} = \frac{670+453}{580} = 1.93 \text{ (N/mm)}.$$

Reaction of left bearing:

$$R_1 = \frac{(Q * w_P \cdot \left(\frac{w_P}{2} + w_3\right) + F_m * (w_1 + w_2 + w_3 + w_p)}{w_2 + w_3 + w_p}$$

$$= \frac{(1.93*580*\left(\frac{580}{2}+30\right)+627.3*(125+30+30+580)}{30+30+580} = 1309.5 \text{ (N)}.$$

Reaction of right bearing:

$$R_2 = F_x + Q * w_P - R_1 = 624.9+1.93*580-1309.5=434.8\text{(N)}.$$

Total bending torque:

$$M_1 = \sqrt{M_{1x}^2 + M_{1y}^2} = \sqrt{78.1^2 + 6.8^2} = 78.4\text{(N*m)}.$$

The material of UNS G10450 (it is a carbon steel which content of carbon is from 0.43 to 0.50 and it is manufactured by foundry in China) will be used in my design shaft because it has characteristic of high toughness and strength and often be used in manufacture the shaft.

The strength date of choosen material:

- Yield strength, S_y = 450 Mpa;
- ultimate strength, S_u = 675 Mpa;
- safety factor of shaft, SF_s = 29 (which is equal to SF_b).

Endurance strength:

$$S_e = 0.55 * 1 * 0.814 * 1 * 1 * (0.5* S_u) = 151 \text{ (Mpa)}.$$

Determination of the minimum shaft diameter:

$$d_m = \left\{ \frac{32 * SF_s}{\pi} * \left[\left(\frac{T_t}{S_y} \right)^2 + \left(\frac{M_1}{S_e} \right)^2 \right]^{0,5} \right\}^{0.33}$$

$$= \left\{ \frac{32*29}{3.14} * \left[\left(\frac{16.31}{450} \right)^2 + \left(\frac{78.4}{151} \right)^2 \right]^{0.5} \right\}^{0.33} = 11(\text{mm}).$$

The diameter of the shaft will be 15mm to satisfy the standard diameter of the ball bearing.

Choice of commercial parts. according to above calculation, I will choose the standard ball bearing (the standard ball bearing is selected from ‘Shandong Linqing zhuochi bearing manufacturer’). The material of the ball bearing is chromium and the type of lubrication is grease. It has following characteristic (Table.2.3) and could satisfy my design requirement:

Table.2.3 - Characteristic of choosen ball bearing

Bearing type		Dimension(mm)			Rated dynamic load (KN)	MAX rotation	Weight(kg)
present	Original	d	D	B	Cr	Grease	
6002	102	15	32	9	2.85	23000	0.03

The standard sprocket which has the number ‘08A-13’ will be used on the drive shaft, d is equal to 15mm, D is equal to 52mm, 13 teeths.

The standard sprocket which has the number ‘08A-17’ will be used on the output gear box shaft, d is equal to 20 mm, D is equal to 68 mm, 17 teeths.

50 steel chain parts will entangle between the two sprockets to transfer power.

2.5.7. Design the idle roller

The length of the conveyer belt is 1.6m, the height of standard passenger bagger is about 0.52m. we must make sure one passenger bagger is supported by two rows of idle roller during conveying. So three rows of idle roller will be installed on the conveyor belt and the distance between each roller is

$$1.6/4=0.4(m).$$

One row of idle roller consists of three rollers which is at different angles. during conveying two rows of idle roller will support the items which means six rollers will support the items, each roller will withstand:

$$F_r=\frac{W}{6}=\frac{25}{6}=4.17(kg).$$

For the selection material for the roller, I have chosen the aluminum alloy due to its high corrosion resistance, suitable for tough working environments and light weight.

For the metal for the roller axes I have chosen aluminum alloy 6061-T6. It has high strength and hardness, it also has good toughness and quite suit for roller axes, the ultimate strength σ_T is equal to 241Mpa.

Shear force:

$$S=\frac{F_r*g}{2}=\frac{F_r*g}{2}=20.9(N).$$

Allowed shear stress:

$$\tau_{c_P}=0.3*\sigma_T=0.3*241=72.3(Mpa).$$

Calculation the diameter of the axis:

$$d = SF_a * \sqrt{\frac{4*s}{\pi*i*z*\tau_{cP}}} = 20 * \sqrt{\frac{4*20.9}{3.14*4*1*72.3}} = 6 \text{ (mm)}.$$

Where i is number of cross section equal to 4, z is number of axes equal to 1, SF_a is safety factor equal to 20.

2.6. Conclusion to the special part

The purpose of the work is Preliminary design of the conveyor belt which is installed on the cargo door for loading and unloading passenger baggage.

During the second part of project, I have got the result of preliminary design of the convey belt which includes:

- The safety factor of the belt is equal to 29, the strength of the selected belt is adequate,
- the diameter of the driven shaft is 15 mm;
- the diameter of the roller shaft is 6 mm;
- the pulley deflection under maximum load is approximately equal to 0 mm;
- selection standard ball bearing made by Shandong bearing manufacturer;
- selection standard aviation motor (MOT) 443MC17 which is manufactured by ‘Western Applied Technologies’;
- gear box ratio is 11.25.

The proposal of the preliminary design of the conveyor belt is feasible because it strictly follow the principle of mechanics of material.

GENERAL CONCLUSION

During this diploma work, I have got the result of preliminary design of the short-range passenger aircraft with 68 passenger capacity which includes:

- Brief description of the main parts in the designed aircraft;
- geometry for the main parts of the designed aircraft;
- furniture layout in the designed aircraft;
- species and position of the engine;
- aircraft center of gravity position;
- configuration of landing gear.

The designed airplane will provide great passenger comfort during flight due to its reasonable layout, good in-flight service, adequate entertainment, convenient service facilities, and smooth experience.

The proposal of the preliminary design of the aircraft is feasible because it strictly follow the requirement of FAR-25, CS-25 and CCAR-25.

I also got the result of preliminary design of the convey belt which includes:

- The main requirements for conveyor belt;
- brief description of the main parts of the designed convey belt;
- geometry and strength calculations for the main parts of the designed conveyor belt;
- select the material for pulley, shaft and belt;
- selection of standard electrical motor, pulley and ball bearing for the designed convey belt.

The proposal of the preliminary design of the conveyor belt is feasible because it strictly follow the principle of mechanics of material.

REFERENCES

1. Mohammad H.. Sadraey Aircraft Design A Systems Engineering Approach. Daniel Webster College. New Hampshire, USA. 2013.
2. Mihaela Florentina. Aircraft Design Studies Based on the ATR 72. Brno University of Technology. 2018.
3. K. P. Shah. Construction and Maintenance of Belt Conveyors for Coal and Bulk Material Handling Plants. 2018.
4. Pelayo Lopez Garcia. Design a Belt Conveyor for iron ore. 2016.
5. Free-Conveyor-Design. www.packexone.com.
6. https://uk.wikipedia.org/wiki/ATR_72.
7. https://www.flight-mechanic.com/landing-gear-types-landing-gear-arrangement/.
8. Federal Aviation Regulations, part 25.
9. Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes, C-25.
10. Civil Aviation Regulation of China, CCAR-25.
11. https://www.atr-aircraft.com/our-aircraft/atr-72-600/.
12. https://en.wikipedia.org/wiki/Aircraft_flight_control_system.
13. https://www.elixirphil.com/types-conveyor-belts-applications/.

APPENDIX A

INITIAL DATE

Student: Wang Junhan   Supervisor of diploma work: M.V. Karuskevich

Date: 1/10/2020

INITIAL DATA AND SELECTED PARAMETERS

I. Passenger Number 68

II. Flight Crew Number 2

Flight Attendant or Load Master Number 2
Mass of Operational Items 614.58kg
Payload Mass 7315kg

Cruising Speed 510km/h
Cruising Mach Number 0.4474
Design Altitude 6.1km
Flight Range with Maximum Payload 1528km
Runway Length for the Base Aerodrome 1.9km

Engine Number 2
Thrust-to-weight Ratio in N/kg 0.16
Pressure Ratio 7.65
Assumed Bypass Ratio 0.22
Optimal Bypass Ratio
Fuel-to-weight Ratio

Aspect Ratio 12
Taper Ratio 2
Mean Thickness Ratio 0.147
Wing Sweepback at Quarter Chord 7
High-lift Device Coefficient 0.58
Relative Area of Wing Extensions 0.05
Wing Airfoil Type
Winglets
Spoilers

Fuselage Diameter 2.57
Finess Ratio 10.6
Horizontal Tail Sweep Angle 3
Vertical Tail Sweep Angle 25

III. CALCULATION RESULTS

IV. Optimal Lift Coefficient in the Design Cruising Flight Point 0.46976

Induce Drag Coefficient 0.01005

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

V. Cruising Mach Number 0.44737

Wave Drag Mach Number 0.64632

Calculated Parameter D_m 0.19894

Wing Loading in kPa (for Gross Wing Area):
At Takeoff 3.257
At Middle of Cruising Flight 3.078
At the Beginning of Cruising Flight 3.188

Drag Coefficient of the Fuselage and Nacelles 0.00701
Drag Coefficient of the Wing and Tail Unit 0.01005

Drag Coefficient of the Airplane:
At the Beginning of Cruising Flight 0.03198
At Middle of Cruising Flight 0.03162
Mean Lift Coefficient for the Ceiling Flight 0.46976

Mean Lift-to-drag Ratio 14.85676

Landing Lift Coefficient 1.560
Landing Lift Coefficient (at Stall Speed) 2.340
Takeoff Lift Coefficient (at Stall Speed) 2.079
Lift-off Lift Coefficient 1.497
Thrust-to-weight Ratio at the Beginning of Cruising Flight 0.112
Start Thrust-to-weight Ratio for Cruising Flight 0.164
Start Thrust-to-weight Ratio for Safe Takeoff 0.185

Design Thrust-to-weight Ratio 0.190

Ratio $D_r = R_{cruise} / R_{takeoff}$ D_r 0.888

SPECIFIC FUEL CONSUMPTIONS (in kg/kN*h):
Takeoff 0.2751
Cruising Flight 0.2365
Mean cruising for Given Range 0.2385

FUEL WEIGHT FRACTIONS:
VI. Fuel Reserve 0.02823
Block Fuel 0.10778

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:
Wing 0.13087
Horizontal Tail 0.01715
Vertical Tail 0.01948
Landing Gear 0.04807
Power Plant 0.14951-fuel
Fuselage 0.11475
Equipment and Flight Control 0.14075
Additional Equipment 0.00153
Operational Items 0.01875
Fuel 0.13601
Payload 0.22312

Airplane Takeoff Weight 32785kg
Takeoff Thrust Required of the Engine 3115.9

Air Conditioning and Anti-icing Equipment Weight Fraction 0.0234
Passenger Equipment Weight Fraction 0.0176
(or Cargo Cabin Equipment)
Lining and inclusion-Interior Panels and Thermal/Acoustic Blanketing Weight Fraction 0.0086
Furnishing Equipment Weight Fraction 0.0071
Flight Control Weight Fraction 0.0087
Hydraulic System Weight Fraction 0.0219
Electrical Equipment Weight Fraction 0.0299
Radar Weight Fraction 0.0044
Navigation Equipment Weight Fraction 0.0066
Radio Communication Equipment Weight Fraction 0.0033

Instrument Equipment Weight Fraction 0.0077
Fuel System Weight Fraction 0.0039

Additional Equipment:

Equipment for Container Loading 0
No typical Equipment Weight Fraction 0.0015
(Build-in Test Equipment for Fault Diagnosis,
Additional Equipment of Passenger Cabin)

VII. TAKEOFF DISTANCE PARAMETERS

VIII. Airplane Lift-off Speed 210.86km/h

Acceleration during Takeoff Run 2.37
Airplane Takeoff Run Distance 721m
Airborne Takeoff Distance 578m
Takeoff Distance 1299

IX. CONTINUED TAKEOFF DISTANCE PARAMETERS

X. Decision Speed 200.32km/h

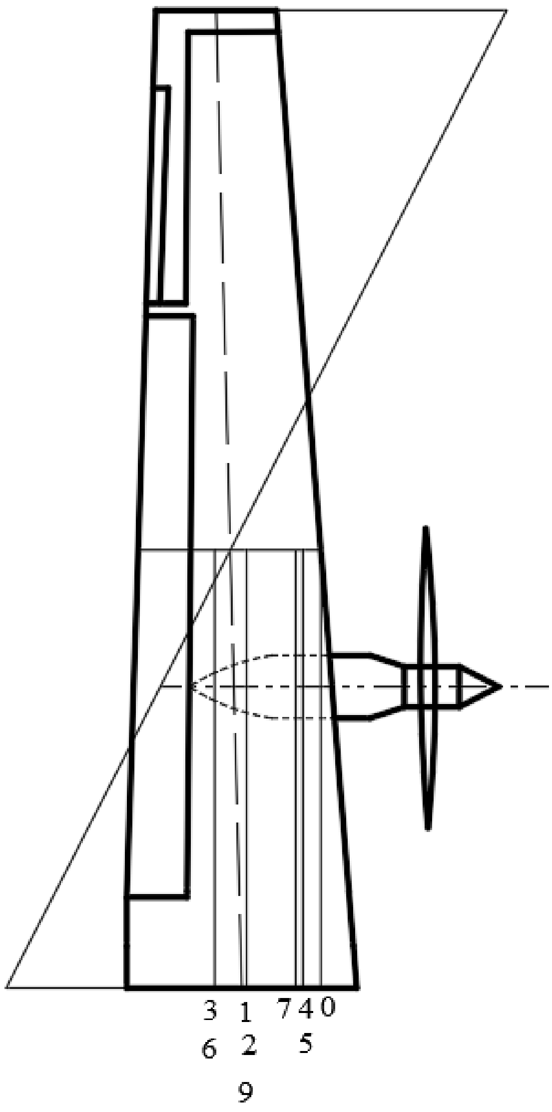
Mean Acceleration for Continued Takeoff on Wet Runway 0.43
Takeoff Run Distance for Continued Takeoff on Wet Runway 1027.59m
Continued Takeoff Distance 1573.85m
Runway Length Required for Rejected Takeoff 1645.23m

XI. LANDING DISTANCE PARAMETERS

XII. Airplane Maximum Landing Weight 30640kg

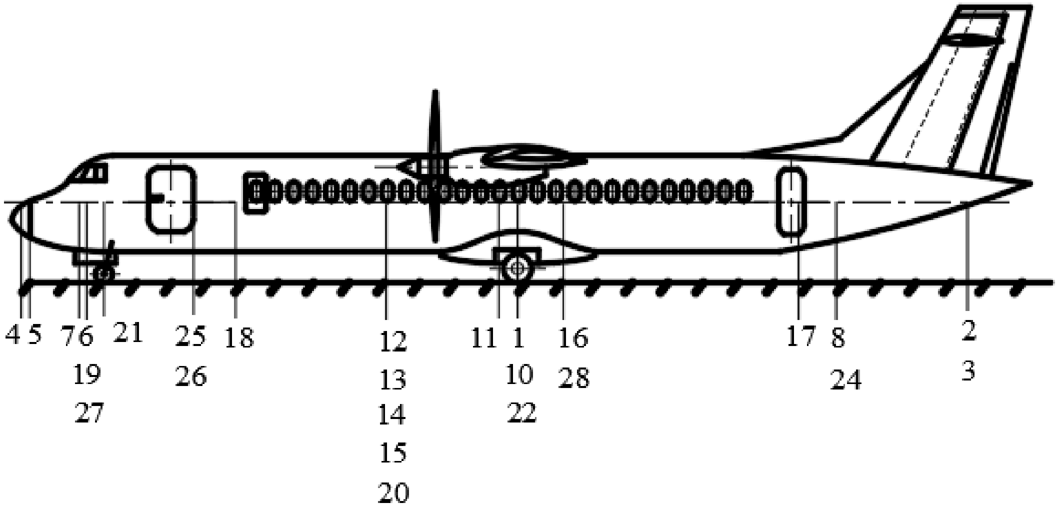
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight 12.7
Descent Distance 17.97km
Approach Speed 216.21km/h
Mean Vertical Speed 1.8m/s
Airborne Landing Distance 512m
Landing Speed 200.91km/h
Landing run distance 659m
Landing Distance 1206m
Runway Length Required for Regular Aerodrome 2015m
Runway Length Required for Alternate Aerodrome 1713m

APPENDIX B



Aircraft design department				NAU 21 07W 00 00 00 44 CG			
Sheet	Document N°	Sign	Date	Short-range Passenger aircraft	letter	Weight	Scale
Performed	Wang Junhan						1:75
Cheked	M. V. Karuskevich				Sheet 1		sheet 2
Reviewd				CG of wing	402 AF 134		
Approved							

APPENDIX C



Aircraft design department				NAU 21 07W 00 00 00 44 CG			
				Short-range Passenger aircraft	letter	Weight	Scale
Sheet	Document N°	Sign	Date				1:150
Performed	Wang Junhan				Sheet 1	sheet 2	
Cheked	M. V. Kruskevich			CG of fuselage	402 AF 134		
Reviewd							
Approved							