МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ
Національний авіаційний університет
Кафедра конструкції літальних апаратів

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри, д.т.н., проф.
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КВАЛІФІКАЦІЙНА РОБОТА
ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ
«БАКАЛАВР»

Тема: «Аванпроєкт дальньомагістрального вантажного літака з удосконаленим верхнім завантажувальним обладнанням»

Виконав: __________ **Денис ЮРЧИК**

Керівник: д.т.н., проф. __________ **Михайло КАРУСКЕВИЧ**

Нормоконтролер: к.т.н., доц. __________ **Володимир КРАСНОПОЛЬСЬКИЙ**

Київ 2023

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
National Aviation University
Department of Aircraft Design

PERMISSION TO DEFEND
Head of the department,
Professor, Dr. of Sc.
_________ Sergiy IGNATOVYCH
"___" ____________ 2023

BACHELOR DEGREE THESIS

Topic: " Preliminary design of long range freighter with improved overhead loading equipment "

Fulfilled by: ____________ **Denys YURCHYK**

Supervisor:
Dr. of Sc., Professor ____________ **Mykhailo KARUSKEVYCH**

Standards inspector
PhD, associate professor ____________ **Volodymyr KRASNOPOLSKYI**

Kyiv 2023

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Аерокосмічний факультет
Кафедра конструкції літальних апаратів
Освітній ступінь «Бакалавр»
Спеціальність 134 «Авіаційна та ракетно-космічна техніка»
Освітньо-професійна програма «Обладнання повітряних суден»

ЗАТВЕРДЖУЮ
Завідувач кафедри, д.т.н, проф.
__________ Сергій ІГНАТОВИЧ
«___» ____________ 2023 р.

ЗАВДАННЯ

на виконання кваліфікаційної роботи здобувача вищої освіти

ЮРЧИКА ДЕНИСА ЮРІЙОВИЧА

1. Тема роботи: «Аванпроєкт дальньомагістрального вантажного літака з удосконаленим верхнім завантажувальним обладнанням», затверджена наказом ректора від 1 травня 2023 року № 624/ст.
2. Термін виконання роботи: з 29 травня 2023 р. по 25 червня 2023 р.
3. Вихідні дані до роботи: маса комерційного навантаження 90000 кг, дальність польоту з максимальним комерційним навантаженням 9500 км, крейсерська швидкість польоту 895 км/год, висота польоту 11,5 км, габаритні розміри вантажної кабіни.
4. Зміст пояснювальної записки: вступ, основна частина, що включає аналіз літаків-прототипів і короткий опис проектованого літака, обґрунтування вихідних даних для розрахунку, розрахунок основних льотно-технічних та геометричних параметрів літака, компонування пасажирської кабіни, розрахунок центрування літака, спеціальна частина, яка містить вимоги до телферів та їх реалізацію.
5. Перелік обов’язкового графічного (ілюстративного) матеріалу: загальний вигляд літака (А1×1), компонувальне креслення фюзеляжу (А1×1),

складальне креслення тельферної системи (А1×1).

6. Календарний план-графік:

№	Завдання	Термін виконання	Відмітка про виконання
1	Вибір вихідних даних, аналіз льотно-технічних характеристик літаків-прототипів.	29.05.2023 – 31.05.2023	
2	Вибір та розрахунок параметрів проєктованого літака.	01.06.2023 – 03.06.2023	
3	Виконання компонування літака та розрахунок його центрування.	04.06.2023 – 05.06.2023	
4	Розробка креслень по основній частині дипломної роботи.	06.06.2023 – 07.06.2023	
5	Огляд літератури за проблематикою спеціальної частини роботи. Аналіз варіантів завантаження дальньомагістральних літаків.	08.06.2023 – 09.06.2023	
6	Розрахунок елементів тельферу.	10.06.2023 – 11.06.2023	
7	Оформлення пояснювальної записки та графічної частини роботи.	12.06.2023 – 14.06.2023	
8	Подача роботи для перевірки на плагіат.	15.06.2023 – 18.06.2023	
9	Попередній захист кваліфікаційної роботи.	19.06.2023	
10	Виправлення зауважень. Підготовка супровідних документів та презентації доповіді.	20.06.2023 – 22.06.2023	
11	Захист дипломної роботи.	23.06.2023 – 25.06.2023	

7. Дата видачі завдання: 29 травня 2023 року

Керівник кваліфікаційної роботи ____________ Михайло КАРУСКЕВИЧ

Завдання прийняв до виконання ____________ Денис ЮРЧИК

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty
Department of Aircraft Design
Educational Degree "Bachelor"
Specialty 134 "Aviation and Aerospace Technologies"
Educational Professional Program "Aircraft Equipment"

APPROVED BY
Head of Department,
Professor Dr. of Sc.
________ Sergiy IGNATOVYCH
«___» ____________ 2023

TASK

for the bachelor degree thesis

Denys YURCHYK

1. Topic: " Preliminary design of long range freighter with improved overhead loading equipment ", approved by the Rector's order № 624/ст from 1 May 2023.
2. Period of work: since 29 May 2023 till 25 June 2023.
3. Initial data: payload 90 tons, flight range with maximum capacity 9500 km, cruise speed 895 km/h, flight altitude 11,5 km, cargo cabin dimensions.
4. Content (list of topics to be developed): introduction, main part: analysis of prototypes and brief description of designing aircraft, selection of initial data, wing geometry calculation and aircraft layout, landing gear design, engine selection, center of gravity calculation, special part: introduction and preliminary design of telfer system.
5. Required material: general view of the airplane (A1×1), layout of the airplane (A1×1), design of the mechanism for loading of oversized cargo (A1×1).

6. Thesis schedule:

№	Task	Time limits	Done
1	Selection of initial data, analysis of flight technical characteristics of prototypes aircrafts.	29.05.2023 – 31.05.2023	
2	Selection and calculation of the aircraft designed parameters.	01.06.2023 – 03.06.2023	
3	Performing of aircraft layout and centering calculation.	04.06.2023 – 05.06.2023	
4	Development of drawings on the thesis main part.	06.06.2023 – 07.06.2023	
5	Cargo loading planning analysis for long range aircraft.	08.06.2023 – 09.06.2023	
6	Calculation of the elements of the telfer system.	10.06.2023 – 11.06.2023	
7	Explanatory note checking, editing, preparation of the diploma work graphic part.	12.06.2023 – 14.06.2023	
8	Submission of the work to plagiarism check.	15.06.2023 – 18.06.2023	
9	Preliminary defense of the thesis.	19.06.2023	
10	Making corrections, preparation of documentation and presentation.	20.06.2023 – 22.06.2023	
11	Defense of the diploma work.	23.06.2023 – 25.06.2023	

7. Date of the task issue: 29 May 2023

Supervisor: ____________ Mykhailo KARUSKEVICH

Student: ____________ Denys YURCHYK

РЕФЕРАТ

Пояснювальна записка кваліфікаційної роботи бакалавра «Аванпроєкт дальньомагістрального вантажного літака з удосконаленим верхнім завантажувальним обладнанням»:

56 с., 7 рис., 10 табл., 9 джерел

Мета роботи - розробка аванпроєкту вантажного літака для дальньомагістральних авіаліній з удосконаленим верхнім завантажувальним обладнанням, що відповідає міжнародним стандартам польотів, нормам безпеки, економічності та надійності, а також проєктування тельферної системидля присткорення та спрощеня завантаження та розвантаження літака.

В роботі було використано методи порівняльного аналізу літаків-прототипів для вибору найбільш обґрунтованих технічних рішень, компьютерного проєктування за допомогою CAD/CAM/CAE систем, ескізного проєктування тельферу з використанням технічних даних подібних пристроїв.

Практичне значення результату кваліфікаційної роботи полягає в підвищенні надійності та ефективності вантажних повітряних перевезень, обґрунтовання застосування тельферної системи, що підвищує зручність робіт, зменшує стомлюваність персоналу та пришвидшує операції завантаження-розвантаження.

Матеріали кваліфікаційної роботи можуть бути використані в авіаційній галузі та в навчальному процесі авіаційних спеціальностей.

Дипломна робота, аванпроєкт літака, компонування, центрування, тельфери, розрахунок конструкції елементів

ABSTRACT

Bachelor degree thesis " Preliminary design of long range freighter with improved overhead loading equipment "

56 pages, 7 figures, 10 tables, 9 references

The aim of the qualification work is development of a preliminary design for a cargo aircraft for long-haul airlines with an improved upper loading equipment that complies with international flight standards, safety regulations, economic efficiency, and reliability. It also involves the design of a trolley system to facilitate and streamline the loading and unloading of the aircraft.

The work utilized the method of comparative analysis of prototype aircraft to select the most justified technical solutions, computer-aided design using CAD/CAM/CAE systems, and sketch design of the trolley system based on technical data from similar devices.

The practical significance of the results of this qualification work lies in enhancing the reliability and efficiency of air cargo transportation, justifying the use of a trolley system that improves work convenience, reduces personnel fatigue, and speeds up loading and unloading operations.

The materials of this qualification work can be applied in the aviation industry and in the educational process of aviation specialties.

Bachelor thesis, aircraft preliminary design, layout, center of gravity calculation, telfers, component calculation

Format	№	Designation	Name	Quantity	Notes
			General documents		
A4	1	NAU 23 13Y 00 00 00 28 TW	Task for work	1	
	2	NAU 23 13Y 00 00 00 28	Long-range cargo aircraft	2	
A1		Sheet 1	General view		
A1		Sheet 2	Fuselage layout		
A4	3	NAU 23 13Y 00 00 00 28 EN	Long-range cargo aircraft	59	
			Explanatory note		
			Documentation for assembly units		
A1	4	NAU 23 13Y 00 00 00 28	Design of telfer system	1	

NAU 23 13Y 00 00 00 08 EN

Done by	Yurchyk D.Y.			Preliminary design of long range freighter with improved overhead loading equipment (List of diploma work)	list	sheet	sheets
Supervisor	Karuskevich M.V.				Q	9	59
					ASF 402		
St.control.	Krasnopolskii M.V.						
Head of dep.	Ignatovich S.R.						

CONTENT

INTRODUCTION

The advent of human flight not only boosted our power of movement, but also enhanced our vision: We gained the ability to see the Earth from above. Before the Wrights' epochal breakthrough, there had been perhaps thousands of human flights, mostly in balloons. But it was the advent of the airplane—a whole new way of seeing and experiencing our planet with speed and control—that led to euphoric reactions across the world.

In today's world, planes allow fast and practical air travel for passengers traveling around the world. Planes are engineered with aerodynamic rules to be able to fly. In addition to passenger planes, there are also many cargo planes. They play an important logistical role in delivering goods around the world quickly and relatively cheap.

We need the advantages of aircraft such as:

1. Low cost of cargo transportation. In order for our aircraft to be in demand and also be profitable for the buyer.

1. High speed. With limited time, it is very convenient to use an airplane that can deliver cargo for thousands of kilometers in a few hours.

2. High commercial load. With the ability to deliver heavier loads, we gain an advantage increasing the variety of these cargoes.

So, the goal of the project is to create a 90 tons payload capacity aircraft and the design analysis and the selection of the optimal characteristics of the hoist system for its further installation on the project aircraft are applied. The use of a hoist system which increases the convenience of work, reduces fatigue of personnel and speeds up loading and unloading operations.

1. ANALYSIS OF PROTOTYPES OF LONG-RANGE AIRCRAFT

1.1 Analysis of prototypes and short description of designed aircraft

The process of aircraft design involves understanding the design requirements, modifying the design variables, and establishing an overall concept for the aircraft. These design variables, known as airplane design parameters, are responsible for determining the aircraft's performance during flight. In order to establish a general concept, a set of design parameters must be determined, including the aircraft's mass, various components, geometric properties, and engine performance.

During the initial stages of the design, selecting all the parameters at once can be challenging, often requiring a preliminary selection based on statistical analysis. This analysis relies on the designers' experience and decisions regarding similar aircraft. If the new aircraft being designed is intended to succeed an existing one and the performance requirements are not significantly different, or there are only minor differences in specific areas, the original aircraft can serve as a prototype. The prototype for the designed aircraft in this work is Boeing 777 Freighter. Statistic data of prototype are presented in table 1.1.

Table 1.1

Performances of prototype – Boeing 777 Freihgter

Name and dimensionality	B 777F	B 747 LCF	AN-124-100M-150	Project
Max payload, kg	103 000	113 400	150 000	90000
Crew, number of pilot	2	2	4	2
Passengers (max)	-	-	-	-
Wing loading, kN/m^2	7.8	7.48	6.27	6.22

End of the table 1.1

Flight range with max paylod, [km]	9047	7800	3200	9500
Cruise Altitude, km	13.14	13	11.6	11.5
Thrust/weight ratio, kN/kg	0.0028	0.003	0.0025	0.0029
Number of engines and their type	GE90-110Bx2	PW 4062x4	D-18T Series 4x4	GE90-110Bx2
Pressure ratio	39,3	32,3		39.3
Take off distance, m	2990		2800	2508.96
MTOW Maximum Take Off Mass, [kg]	347,814			401,475
Empty weight, kg	144.379			164 969
Fuel fraction, % Total fuel/MTOW	38			36
Payload fraction, % Maximum payload/MTOW	41.6			22
Wing span, m	60.9	64.4		63.25
Sweepback angle at ¼ of the chord, °	31.64			33
Fuselage length, m	63.7	71.68		62.8
Fuselage diameter, m	6.2			6.2
Vertical tail height, m	18.5			18.5

1.2 Brief description of the main parts of the aircraft

1.2.1 Wing

The airplane's wing is designed as a cantilever type with a supercritical rear-loaded airfoil. To accommodate short and medium flight distances, the design cruising speed is reduced to M 0.76-0.78. This reduction is necessary because the wing's characteristics change minimally with the cruising speed, resulting in low aerodynamic drag throughout its operating range. The thickness of the rear beam of the airfoil has been increased by 30% to provide ample space for the flaps and their control system.

The wing incorporates several features to enhance its performance. It utilizes "wingtip sails," with a rounded leading edge and a wedge-shaped trailing edge. Additionally, a "spindle" extends backward along the chord of the wing to mitigate induced drag. Compared to traditional "winglets," this design offers superior drag reduction even in non-ideal conditions, ensuring that the "wingtip sail" remains unstalled when crosswinds are present.

The full wingspan leading edge slat is divided into five sections. Given the close proximity of the engine nacelle to the lower surface of the wing, modifications have been made to the engine pendant to optimize the opening position of the leading edge slat without compromising high-speed cruise performance. The inner and outer trailing edge flaps are equipped with large single-slot Fowler flaps. The wing features five spoilers on each side, positioned on the upper surface. Two inner spoilers serve as speed brakes, while three outer spoilers are responsible for roll control. During landing, all five spoilers work together to reduce lift force. The inboard ailerons have been eliminated to improve the spanwise length of the trailing edge flaps during take-off and landing, thereby increasing lift efficiency. Various components of the wing, including the fixed panels at the front and rear edges, trailing edge flaps, flap fairings, spoilers, ailerons, and wing root fairings, are constructed using composite materials. This choice of materials offers advantages in terms of strength, weight reduction, and overall performance.

1.2.2 Fuselage

The fuselage of the aircraft incorporates a semi-monocoque structure. The longest section of the fuselage is the equal-diameter portion, which houses the passenger cabin. To minimize aerodynamic resistance, a waist-shaped rear fuselage section has been implemented. The structure of the fuselage is composed of a series of frames, stringers, beams, and a working skin. These components work together to provide strength and support to the fuselage. Frames are structural elements that help maintain the shape and rigidity of the fuselage. Stringers run longitudinally along the fuselage and provide additional reinforcement. Beams are structural members that bear loads and distribute them throughout the fuselage structure. The working skin covers the frame and stringer structure, providing a smooth outer surface for the fuselage. This semi-monocoque design offers a balance between weight efficiency and structural integrity. The combination of frames, stringers, beams, and working skin ensures that the fuselage can withstand the various stresses encountered during flight, while also providing an efficient use of materials.

1.2.3 Tail unit

The aircraft's tail unit includes the horizontal and vertical stabilizers, elevators, and rudder. It has a conventional configuration. The horizontal tail features reverse camber to enhance flight stability. The elevator is operated using a fly-by-wire control system, while the rudder is controlled hydromechanically. Both the horizontal and vertical stabilizers are constructed using full-composite structures, offering lightweight and durable properties.

1.2.4 Landing gear

The landing gear system consists of two retractable main landing gear and one retractable nose landing gear. All landing gear struts and their hatches are controlled using hydraulic and electrical systems. The hatches connected to the landing gear struts are mechanically driven, closing when the landing gear is fully retracted. During the process of retracting and extending the landing gear, all landing gear hatches are opened.

The landing gear retraction is carried out hydraulically. Each landing gear consists of a two-wheeled strut equipped with oil-gas shock absorbers. The main landing gear is housed within the wing-fuselage fairing. The nose gear has the capability to turn and move forward into the fuselage. The main landing gear hatch is constructed using composite materials, which offer advantages such as lightweight and high strength-to-weight ratio.

1.2.5 Control system

The fly-by-wire control system governs the entire flight process, from take-off to landing. It consists of two independent systems with a total of five computers. Two computers control the elevator and aileron, while three computers are responsible for spoiler control. Rudder trim is handled by two flight stabilization computers, and the slats and flaps are controlled by two specialized computers. The fly-by-wire system enhances flight safety and reduces pilot workload significantly. To enhance the reliability of the fly-by-wire control system, two measures have been implemented. Firstly, signal transmission cables leading to each control surface are separated from one another. For example, the aileron and spoiler cables are respectively routed before and after the wing front beam. Secondly, to safeguard against lightning strikes, all teleflex control cables are encased in metal shielding sleeves, with exposed sections shielded within cable ducts. The flight control system employs side sticks instead of conventional control sticks and handwheels, reducing the overall system weight. The side stick control system includes a tiltable joystick, a roll and pitch sensor box, and an artificial sensor system. During autopilot operation, an electromagnetic coil-driven bayonet locks the control system in a neutral position. An electronic circuit connects the two fly-by-wire control devices. Under normal circumstances, two pilots cannot operate the aircraft simultaneously. To address conflicting control inputs, a comparison device is installed in the electronic circuit. The fly-by-wire system can superimpose the two input signals, and if one pilot wishes to override the other's input, they can press and hold the "takeover button" to release the other party's input. The hydraulic systems are color-coded into three groups: green, yellow, and blue. The green and yellow systems are interconnected, with each engine driving one of them. The blue hydraulic system is powered by air ram wheels and comprises three engines, two of which are driven by the engines for normal power supply, while the third engine is driven by an auxiliary power unit. The blue hydraulic system can also serve as an emergency backup for in-flight power supply and is also utilized on the ground. In the event of all three engines failing, there is a 5,000 VA emergency engine driven by the blue hydraulic system. A converter is also installed to provide DC power, along with a backup battery.

1.2.6 Onboard equipment

The aircraft is equipped with a two-person "glass" cockpit where all the controls for the aircraft systems are located on the top panel. The display system belongs to the second generation, comprising three display management computers and two system data acquisition devices. It integrates with the fly-by-wire control system and the second-generation digital automatic flight system.With this integration, there is no need for separate guidance computers, engine thrust control computers, or independent servo mechanisms for autopilot and auto throttle. These functions are all encompassed within the flight management computer. The computer's command signals are transmitted to the pitch control through the fly-by-wire control computer, while the roll control surface is managed by the flight stabilization computer, which also controls the yaw. The thrust control is handled by the engine's full-function electronic control system. This streamlined approach reduces the number of computers required for the automatic flight control system to just six, enhancing safety, reliability, and system simplicity while reducing costs and aircraft weight.A centralized fault display system is implemented, featuring two cathode-ray tubes located at the center of the instrument panel. These display warning signals and system movements in case of aircraft system failures. The integrated failure display system automatically analyzes the cause of the failure, eliminating the need for excessive manual reading and reference to documents.Each cabin crew member's position is equipped with a communication system, including a telephone and a flight attendant panel. The cabin door is equipped with a single-channel evacuation slide, which features a lighting system for enhanced visibility during emergency situations. Oxygen masks are located above each cabin crew member's position, along with other essential emergency equipment.

1.2.7 Choice and description of power plant

For this project was chosen GE90-110Bx2 according its take-off thrust that is obtained from the calculation. The General Electric GE90 is a family of high-bypass turbofan aircraft engines built by GE Aviation for the Boeing 777. The data of these engines are presented in table 1.2.

Table 1.2

Engine performances

Model	Thrust	Bypass ratio	Dry weight
GE90-110B	110,760lbf (492.7 kN)	9	19,316 lb (8,762 kg)
PW4062	63,300 (281.81 kN)	4.8	9,570 lb (4,341 kg)
D-18T Series 4	51,590 (230kN)	4	9,039 lb (4,100 kg)

2. PRELIMINARY DESIGN OF LONG-RANGE AIRCRAFT

2.1 Geometry calculations for the main parts of the aircraft

In the design of a future aircraft, the geometrical characteristics play a crucial role in determining its flight characteristics. To achieve an optimal combination of various aircraft details, several factors need to be considered. These include the calculation of the wing design and high lift devices, the geometry of the fuselage and cabin layout, the landing gear design, and the tail unit design.

2.1.1 Wing geometry calculation

The design process of the aircraft involves the utilization of a specialized computer program developed at the Aircraft Design Department of NAU to calculate the initial data. One crucial aspect is determining the geometrical characteristics of the wing based on the take-off weight (m0) and specific wing load (p0).

Wing airfoil: For designing aircraft supercritical airfoil was taken.

Average reletive thickness of the airfoil is 0.100.

Location of the wing on fuselage: lowwing.

Aspect ratio of the wing λ_w=8.00

Taper ratio of the wing η_w =5.00 The taper ratio influences the following quantities: induced drag, structural weight, ease of fabrication.

Sweep back angle of a wing is 33.0

Wing area:

Wing area (S_{wing}) : This is calculated from the wing loading and gross weight which have been already decided, (in appendix A)

$$S_{wing} = \frac{m_0 \cdot g}{P_0} = \frac{404475 \cdot 9.8}{6222} = 632\text{m}^2$$

Where m_o – take off mass of the aircraft;

g – gravitational acceleration,

P_o – wing loading at cruise regime of flight.

So, we take the wing area

$$S_{wing} = 500\text{m}^2.$$

Wing span is:

$$l = \sqrt{S_{wing} \cdot \lambda_W} = \sqrt{500 \cdot 8} = 63.25\text{m}$$

Root chord is:

$$C_{root} = \frac{2S_w \eta_w}{(1+\eta_w) \cdot l} = 13.17\text{m}$$

Tip chord is:

$$C_{tip} = \frac{C_{root}}{\eta_w} = 2.63\text{m}$$

On board chord for trapezoidal shaped wing is:

$$C_{board} = C_{root} \cdot (1 - \frac{(\eta_w - 1) \cdot D_f}{\eta_w \cdot l_w}) = 13{,}17(1 - \frac{(5-1) \cdot 6.2}{5 \cdot 63.25}) = 12.13\text{m}$$

Wing construction and spars position.

To choose the structure scheme of the wing it is necessary to determine the type of its internal design. The torsion box type with three spars was chosen to meet the requirements of strength and at the same time to make the structure comparatively light.

For a wing with three spars:

$$x_{1spar} = 0.15\ C_i; x_{2spar} = 0.4\ C_i; x_{3spar} = 0.65\ C_i.$$

The spars are shown at the drawing (appendix B).

Mean aerodynamic chord definition.

The geometrical method of mean aerodynamic chord determination has been taken, which is presented at Appendix B and at the fig.2.1.

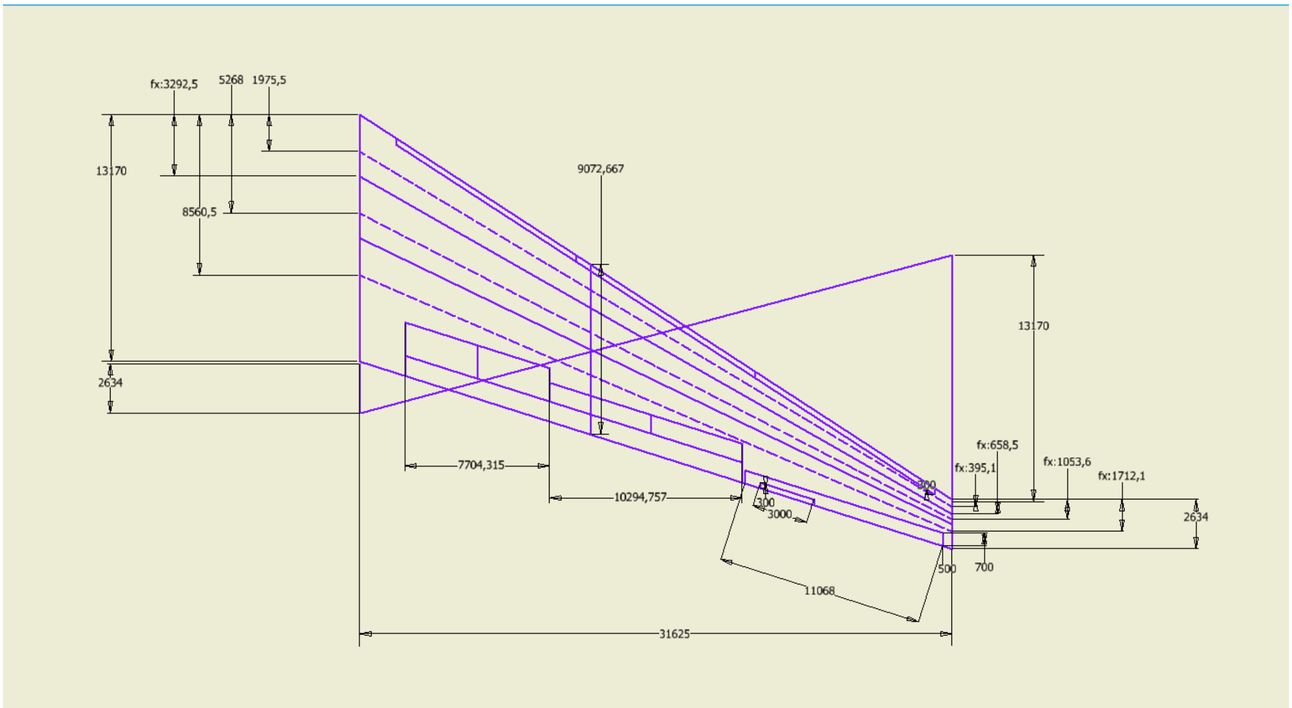

Figure 2.1 – Determination of mean aerodynamic chord.

Mean aerodynamic chord is equal

$$b_{MAC} = 9.07\text{m}.$$

Also we could calculate the MAC by the approximately formulas:

For trapezoidal wing shape:

$$b_{MAC} = \frac{2}{3}\frac{C_{root}^2 + C_{root}C_{tip} + C_{tip}^2}{C_{root} + C_{tip}} = 9.07$$

After determination of the geometrical characteristics of the wing we could come to the estimation of the aileron’s geometry and high-lift devices.

Ailerons design.

The main purpose of the ailerons is to create rolling moment and provide adequate rate of roll. Ailerons geometrical parameters are determined by the next formulas:

Ailerons span:

$$l_{aileron} = 0.35\frac{l_w}{2} = 0.35 \cdot \frac{63.25}{2} = 11.068\text{m}$$

Aileron area:

$$S_{aileron} = 0.06 \cdot \frac{S_w}{2} = 0.06 \cdot \frac{500}{2} = 15\text{m}^2$$

Area of aileron’s trim tab for four engine airplane:

$$S_{trim\ tabs} = 0.06 \cdot S_{aileron} = 0.06 \cdot 15 = 0.9\text{m}^2$$

High lift device of a wing: triple slotted Fowlers flaps together with slats

To keep the lift high (to avoid objects on the ground!), airplane designers try to increase the wing area and change the airfoil shape by putting some moving parts on the wings' leading and trailing edges. The part on the leading edge is called a slat, while the part on the trailing edge is called a flap.

The relative coordination of high-lift devices on the wing chord are:

$$C_f = (0.3..0.4)\ C_i$$

– for three slotted flaps

$$C_s = (0.1..0.15)\ C_i$$

– for slats.

From the list of possible coefficient of high lift devices was chosen one which is answer to high lift devises of designed aircraft.

1.16 – triple slotted Fowlers flaps together with slats coefficient;

2.1.2 Fuselage layout

The aerodynamic and weight characteristics of the fuselage are significant depend on its shapes and sizes, which have become such geometric parameters, such as a long, the form cross section, shape when viewed from the side, elongation and diameter щafuselage It should be remembered that the initial ones are selected the elongation and diameter of the fuselage are further specified at layout of the aircraft with the provision of some internal volumes for the accommodation of the crew, passengers and cargo, as well as for accepted shoulders horizontal and vertical operation of the aircraft.

The front part is the cockpit, the space under the cockpit accommodates many electrical instruments and other devices and the landing gear nose wheel.

The central part of the fuselage is the passenger compartment (or cargo compartment), baggage compartment under the floor, center wing box with fuel tanks and main landing gear wheel well.

The tail of the fuselage consists of the compartment for equipment of systems, smaller forms, spars and stringers. As the formers are smaller but their thickness is constant, they are more rigid so that there are no structural problems to support both the horizontal and vertical stabilizers. The APU (auxiliary power unit) is usually placed at the tail.

In selecting the fuselage parameters, we need to take into account the aerodynamic requirements of the streamline and cross section.

The circular cross-section of fuselage is the most efficient because it provides the minimum weight and maximum strength, meeting strength requirements and reducing weight are important for aircraft design.

We also concentrate on the geometrical parameters, such as: fuselage diameter, length of fuselage, fineness ratio of fuselage, nose part and tail unit geometry (fig.2.3). We design the length of the aircraft fuselage by considering the aircraft purpose, number of passengers, cabin layout, and characteristics of the aircraft's center of gravity position and the landing angle of attack.

Length of the aircraft fuselage:

$$FR = L_{fus} / D_{fus},$$

$$L_{fus} = FR_f \cdot D_{fus} = 6.2 \cdot 10.13 = 62.8\text{m}$$

where:

FR – fineness ratio of the fuselage (from initial data)

D_{fus} – diameter of the fuselage (from initial data)

Length of aircraft fuselage forward part:

The fineness ratio of the fuselage nose part (nose part from the beginning to the end of cone part, after the pilot part)

$$L_{fwd} = FR_{np} \cdot D_{fus} = 1.8 \cdot 6.2 = 11.16\text{m}$$

Length of the fuselage tail part:

$$L_{tailpart} = FR_{tu} \cdot D_{fus} = 2.81 \cdot 6.2 = 17.47\text{m}$$

2.1.3 Layout and calculation of basic parameters of tail unit.

One of the most important tasks of the aerodynamic layout is the choice of tail unit (TU) position.

For ensuring longitudinal stability of the aircraft during maneuvering flight its centre of gravity should be placed in front of the aircraft focus (aerodynamic centre) and the distance between these points (arm for aerodynamic moment of the lift force), related to the mean value of wing aerodynamic chord, determines the rate of longitudinal stability.

Usually the areas of vertical S_{VTU} and horizontal S_{HTU} of TU is:

$$S_{HTU} = (0.18...0.25)S = 90...125\text{m}^2$$

$$S_{VTU} = (0.12...0.20)S = 60...100\text{m}^2$$

For more exact:

$$S_{HTU} = \frac{b_{MAC} \cdot S}{L_{VTU}} \cdot A_{HTU} = \frac{9.072 \cdot 500}{26.6} \cdot 0.55 = 93.8\text{m}^2$$

$$S_{HTU} = \frac{l \cdot S}{L_{VTU}} \cdot A_{HTU} = \frac{63.25 \cdot 500}{26.6} \cdot 0.1 = 95.11\text{m}^2$$

where:

L_{HTU} and L_{VTU} - arms of horizontal TU and vertical TU,

l, S – wing span and wing area.

A_{HTU}, A_{VTU} – coefficients of static moments, values of which may be taken from the table.

Values L_{HTU} and L_{VTU} depend on some factors. First of all their value are influenced by: the length of the nose part and tail part of the fuselage, sweptback and wing location, and also from the conditions of stability and control of the airplane.

In the first approach we may count that $L_{HTU} \approx L_{VTU}$ and we may find it from the dependences:

Trapezoidal scheme, normal scheme

$$L_{VTU} = (0.2..3.5)\ b_{mac}$$

$$L_{VTU} = 3 \cdot 9.072 = 27.2\ \text{m}$$

Determination of the elevator area and direction.

Elevator area:

$$S_{el} = 0.35 \cdot 93.8 = 32.8\ \text{m}^2$$

Rudder area:

$$S_{rudder} = 0.2 \cdot 95.11 = 19\ \text{m}^2$$

Choose the area of aerodynamic balance for $0.3 \le M \le 0.6$

$$S_{ab\ el} = 0.22 \cdot 32.8 = 7.2\ \text{m}^2$$

$$S_{ab\ rudder} = 0.21 \cdot 19 = 3.99\ \text{m}^2$$

The area of trim tab

$$S_{tabs} = 0.1 \cdot 19 = 1.9\text{m}^2$$

Determination of the TU span.

TU span is related to the following dependence:

$$l_{HTU} = 0.4 \cdot 63.25 = 25.3\text{m}$$

In this dependence the lower limit corresponds to the turbo jet engine aircraft, equipped with all-moving stabilization.

The height of the vertical TU h_{vtu} is determined accordingly to the location of the engines. Taking it into account we assume:

Low wing, $EonW,\ M<1$

$$h_{vtu}=0.16\cdot 63.25=10.12\text{m}$$

For high wing airplanes we need to set the upper limit.

Tapper ratio of horizontal and vertical TU we need to choose:

For planes:

$$M<1\ \eta_{htu}=2.5\,\eta_{vtu}=1.25$$

TU aspect ratio

For transonic planes:

$$\lambda_{vtu}=1\ \ \lambda_{htu}=4$$

Determination of TU chords b_{end}, b_{CAX}, b_{root}:

$$b_{tip}=\frac{2S_{htu}}{(\eta_{htu}+1)l_{htu}}=\frac{2\cdot 93.8}{(2.5+1)\cdot 25.3}=2.1\text{m}$$

$$b_{tip}=0.66\frac{\eta^{2}{}_{htu}+\eta_{htu}+1}{(\eta_{htu}+1)}b_{htu\ tip}=3.86\text{m}$$

$$b_{root}=b_{tip}\cdot\eta_{htu}=2.1\cdot 2.5=3.86\text{m}$$

Width/chord ratio of the airfoil.

For horizontal and vertical TU in the first approach,

$$\overline{C}_{TU} \approx 0.8\overline{C}_w .$$

TU sweptback.

TU sweptback is taken in the range 3..5˚, and not more than wing sweptback. We do it to provide the control of the airplane in shock stall on the wing

So, TU sweptback = 34˚

2.1.4 Landing gear design

For aircraft, the landing gear supports the craft when it is not flying, allowing it to take off, land, and taxi without damage. Wheeled landing gear is the most common, with skis or floats needed to operate from snow/ice/water and skids for vertical operation on land. Faster aircraft have retractable undercarriages, which fold away during flight to reduce drag.

Some unusual landing gear have been evaluated experimentally. These include: no landing gear (to save weight), made possible by operating from a catapult cradle and flexible landing deck: air cushion (to enable operation over a wide range of ground obstacles and water/snow/ice); tracked (to reduce runway loading).

In the primary stage of design, when the airplane center-of-gravity position is not defined and there is no drawing of airplane general view, only the part of landing gear parameters may be determined.

The distance from the centre of gravity to the main LG

$$B_m = 0.2 \cdot 9.072 = 1.8 \text{ m}$$

With the large distance the lift of the nose gear during take of is complicated, and with small, the strike of the airplane tail is possible, when the loading of the back of the airplane comes first. Besides the load on the nose LG will be too small and the airplane will be not stable during the run on the slickly runway and side wind.

Landing gear wheel base comes from the expression:

$$B = (0.3..0.4)l_f = (6..10)B_m = 0.36 \cdot 1.8 = 18.8\text{m}$$

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

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

The distance from the centre of gravity to the nose LG

$$B_n = B - B_m = 18.8 - 1.8 = 17 \text{ m}$$

Wheel track is:

$$T = (0.7..1.2)B \le 12m$$

$$T = 0.7 \cdot 18.8 = 12m$$

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

On a condition of the prevention of the side nose-over the value T should be > $2H$.

Wheels for the landing gear is chosen by the size and run loading on it from the take off weight; for the front support we consider dynamic loading also.

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

The load on the wheel is determined:

$$\sum F_z = 0 \rightarrow F_n + F_m = W$$

$$\sum M_0 = 0 \rightarrow F_n B + W B_m = 0$$

$$F_n = \frac{B_m}{B} W\ ,\ F_n = \frac{B_n}{B} W$$

$$F_{main} = \frac{(B - Bm) m_0 \cdot 9.81}{B \cdot n \cdot z}$$

$$= \frac{(18.8 - 1.8) \cdot 401775 \cdot 9.8}{18.8 \cdot 2 \cdot 6} = 297003.6\text{N} = 66968\text{lbs}$$

$$F_{nose} = \frac{Bm \cdot m_0 \cdot 9.81 \cdot K_g}{B \cdot z} = \frac{1.8 \cdot 401775 \cdot 9.81 \cdot 1.8}{18.8 \cdot 2} = 339632.4\text{N} = 76352\text{lbs}$$

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

$K_g =\ 1.5..2.0$ – dynamics coefficient.

By calculated F_{main} and F_{nose} and the value of $V_{take\ off}$ and $V_{landing,}$ pneumatics is chosen from the catalog, the following correlations should correspond.

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

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

For ensuring of airplane pass ability, used on the ground runways, pressure in the wheel pneumatics should range in

$$P = (3..5) 10_5 \text{Pa}\ .$$

Tires was chosen according to the maximum load and landing speed from the Michelin data table.

In table 2.1., table 2.2., table 2.3. and table 2.4. shown all characteristics of tires.

Table 2.1.

Tires descriptions

size			Ply rating	Speed index
M	N	D		
56 X	16		38	250

Table 2.2.

Application rating

Max loading	Inflation pressure(unloaded)	Approx. bottoming load
76 000	315	228

Table 2.3.

Inflated tire dimensions

D_0 MAX	D_0 MIN	W MAX	W MIN	D_S MAX	W_s MAX
55,9	54,8	16,2	15,5	50,85	14,26

Table 2.4.

Rim description

A	D	F	G	D	Qualification standard
width between flangers	speciffied rm diameter	flange height	Min. ledge width	outer flange diameter	
12,75	28	2,25	4,6	32,5	MIL-T-5041

2.2 Center of gravity calculation

2.2.1 Trim-sheet of the equipped wing

Mass of the equipped wing contains the mass of its structure, mass of the equipment

placed in the wing and mass of the fuel. Regardless of the place of mounting (to the wing or to the fuselage), the main landing gear and the front gear are included in the mass register of the equipped wing. The mass register includes names of the objects, mass themselves and their center of gravity coordinates. The origin of the given coordinates of the mass centers is chosen by the projection of the nose point of the mean aerodynamic chord (MAC) for the surface XOY. The positive meanings of the coordinates of the mass centers are accepted for the end part of the aircraft.

In table 2.5. will be shown all masses that located in the wing, in table 2.6. will be shown all masses in fuselage.

Table 2.5.

Trim-sheet of equipped wing masses

N	object name	Mass	C.G coordinates Xi. m		Mass moment. Xi*mi
		units	total mass m(i). kg		
1	wing (structure)	0.098	39718	4.082	162144.44
2	fuel system	0.0114	4589	3.26	14986.85
3	Flight control system . 30%	0.0008	325	5.44	1770.10
4	electrical equipment. 10%	0.0018	731	0.907	662.88
5	anti-ice system . 70%	0.0067	2698	0.907	2447.55
6	hydraulic systems . 30%	0.0026	1060	5.44	5769.22
7	power plant	0.093	37430	-1.6	-59887.22
8	equipped wing without landing gear and fuel	0.21	86550	1.478	127893.81
9	nose landing gear	0.0071	2837	-12.86	-36481.54
10	main landing gear	0.0283	11347	0.82	9304.78
11	fuel	0.36	32842.8	2	65685.6
12	total	0.61	247236	2.043	505135.74

Table 2.6.

Trim-sheet of equipped fuselage masses

	objects names	Mass		C.G coordinates Xi. m	mass moment
		units	total mass		
1	fuselage	0.067	26879	31.403	844073.43
2	horizontal tail	0.0086	3441	67.19	210532.81
3	vertical tail	0.0089	3581	57.431	205670.32
4	radar	0.003	1207.07	1	1207.07
5	radio equipment	0.0023	923	1	923.39
6	instrument panel	0.0053	2128	2	4255.64
7	aero navigation equipment	0.0045	1807	2	3613.28
10	Flight control system 70%	0.0019	759	34.543	26211.03
11	hydraulic system 70%	0.0062	2473	43.9	108568.48
12	electrical equipment 90%	0.0073	2923	31.403	97782.74
13	not typical equipment	0.0028	1124	10	11241.3
14	lining and insulation	0.0125	5018	28.263	141834.59
15	anti ice system. 30%	0.0029	1156	59.743	69077.15
16	airconditioning system. 40%	0.005	2007	28.263	56733.84
17	seats of flight attendence	0.0002	100	6.5	650
18	seats of pilot	0.0002	100	3	300
19	Emergency equipment	0.0045	1815	8.1	14698.8
20	lavatory1. galley 1	0.0007	300	5	1500

21	lavatory2. galley 2	0.0007	300	5	1500
22	Operational items	0.0110	4400	20	88000
23	additional eguipment	0.0025	991	20	19820
24	equipped fuselage without payload	0.159	63839	29.817	1903478.73
25	on board meal	0.00067	60	5	300
26	cargo. mail	0.224	90000	31.403	2826000
27	flight attend	0.0006	240	6.5	1560
28	crew	0.0004	160	3	480
30	TOTAL	0.384	154239	30.677	4731518.73

2.2.2 Determination of the centre of gravity of the equipped fuselage:

Origin of the coordinates is chosen in the projection of the nose of the fuselage on the horizontal axis. For the axis X the construction part of the fuselage is given. The example list of the objects for the AC, which engines are mounted under the wing, is given in table 1.3.2.

The CG coordinates of the FEF are determined by formulas:

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

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

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

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

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

$$\frac{34485.93 \cdot 29.6 + 55514.7 \cdot 164 - 90000 \cdot 2.268}{90000 - 55514.7} = 26.33$$

where m_0 – aircraft takeoff mass, kg;

m_f – mass of fully equipped fuselage, kg;

m_w – mass of fully equipped wing, kg;

C – distance from MAC leading edge to the C.G. point, determined by the designer.

$$C = \left(0,22...0,25\right) B_{MAC}$$

for low wing ;

For swept wings at

$$X = 30°...40° C = \left(0,28...0,32\right)\mathbf{B_{MAC}}$$

at

$$X = 45° C = \left(0,32...0,36\right)\mathbf{B_{MAC}}$$

2.2.3 Calculation of center of gravity positioning variants

The list of mass objects for C.G. variant calculation given in Table 2.7

Table 2.7.

Calculation of the C.G. positioning variants

Name	mass in kg	coordinate	mass moment
object	m_i	X_i, м	Kgm
equipped wing (without fuel and landing gear)	86550	29.998	2596336.32
main landing gear (extended)	11347	29.340	332934.33
fuel reserve	12562	31.696	398165.32
fuel for flight	133940	31.242	4184560.06
Equipped fuselage (without payload)	63839	30.677	1958362.54
cargo, mail	90000	31.4	2826000
flight attend	240	6.500	1560
crew	160	3	480,00
Nose landing gear (retrected)	2837	15.660	44425.85
main landing gear (retrected)	11347	29.340	332934.33

In table 2.8. will be shown position of gravity center in different variants.

Table 2.8.

Airplanes C.G. position variants

№	Object name	Mass, m_i kg	mass moment m_iX_i	enter of mass $X_{цм}$
1	take off mass (L.G. extended)	401475	12342824.43	24.51
2	take off mass (L.G. retracted)	401475	12340498.23	24.44

End of the table 2.8

3	landing weight (LG extended)	267535	8158264.36	21.76
4	ferry version (without payload, max fuel, LG retracted)	311235	9512938.23	22.54
5	parking version (without payload, without fuel foe flight, LG extended)	164573	4932059.04	15.97

Conclusion to the project part

During the design process, the following results have been obtained for the long-range cargo aircraft:

Preliminary design: The preliminary design of the long-range cargo aircraft has been completed, considering its intended payload capacity of 90 tons. This involves determining the overall dimensions, structural configuration, and general layout of the aircraft.

Cabin layout: The cabin layout for the long-range cargo aircraft has been finalized. This includes designing the interior space to accommodate the cargo efficiently and securely, considering factors such as loading/unloading procedures, cargo securing mechanisms, and accessibility for maintenance.

Center of gravity calculations: The calculations for the center of gravity of the aircraft have been performed. Determining the precise location of the center of gravity is crucial for maintaining stability and control during flight, ensuring that the aircraft is properly balanced.

Main geometrical parameters of the landing gear: The main geometrical parameters of the landing gear have been calculated. This includes determining the dimensions, placement, and characteristics of the main landing gear components, such as struts, wheels, and shock absorbers.

Wheel selection: The appropriate wheels that satisfy the requirements of the aircraft have been chosen. Factors such as load-bearing capacity, durability, and compatibility with the runway conditions are considered to ensure safe and efficient ground operations.

Nose landing gear design: The design of the nose landing gear has been completed. This includes determining the dimensions, placement, and functionality of the nose landing gear components, such as the strut, wheel, steering mechanism, and retraction system.

The chosen design of a low-wing aircraft with two engines located under the wing offers advantages such as improved aerodynamic characteristics of the wing, reduced aerodynamic effects from the engines' jet streams, and increased fuelefficiency. This design choice aims to enhance the overall performance and economy of the aircraft.

These results represent significant progress in the design process, laying the foundation for further detailed analysis, engineering, and refinement of the long-range cargo aircraft.

3. THE IMPROVED OVERHEAD LOADING EQUIPMENT

3.1 Application of telfers

Special part of the diploma work deals with conceptual and preliminary design of the telpher proposed for the facilitation of the loading and unloading processes.

A telfer, also commonly referred to as a electrical hoist, is a highly sophisticated piece of machinery that's integral to numerous industries and sectors globally. This piece of equipment plays a critical role in the movement and management of heavy loads, bringing about a significant increase in efficiency and safety in various operations.

The fundamental principle of the telfer lies in its capability to raise or lower a load. This operation is made possible by a drum or a lift-wheel, around which a rope or a chain is wrapped. The fascinating aspect of a telfer's operation is its adaptability - the operation can be either manual, showcasing the simple yet effective nature of its design, or it can be powered by an electric or pneumatic system, reflecting the advances of modern technology. Depending on the specific needs of a task or operation, the lifting medium used may consist of a chain, a fiber, or a wire rope.

The application of telfers is broad and diverse, with the machinery being a crucial component in an array of tasks in different sectors. They are widely used in construction sites for moving heavy materials, in warehouses for efficient material handling, in shipyards for lifting massive ship parts, and even in theatre stages for managing props and sets.

One industry where telfers have demonstrated significant utility is aviation. They are invaluable for their contribution to streamlining the process of loading and unloading heavy goods, ensuring these tasks are carried out efficiently and safely. This is particularly crucial in large commercial aircraft and military cargo planes where heavy goods and materials need to be transported over long distances.

Telfers have an interesting historical trajectory. Their roots can be traced back to antiquity, where rudimentary lifting devices operated through pulleys and levers were used. The progression of human civilization and technology has witnessed the evolution of these basic contrivances into the highly complex machinery that we are familiar with today. This progression is a testament to human innovation and our constant strive to improve efficiency and safety in various industries.

Modern telfers are typically powered by electric or pneumatic systems. Electric telfers incorporate an electric motor into their operation, making them ideal for applications that require continuous and frequent lifting of loads. They are often used in industries where there is a stable power supply and where noise reduction is essential.

On the other hand, pneumatic telfers utilize pressurized air to drive their motion. They are well suited for explosive or flammable environments as they do not produce sparks and can withstand harsh environmental conditions. These telfers are often found in oil rigs, gas plants, and chemical industries.

There are two primary types of telfers: chain and wire rope. The chain variety is celebrated for its durability and suitability for heavy loads, making it a popular choice for many heavy-duty applications. It is typically found in industries like construction, mining, and dockyards.

Wire rope telfers, however, are chosen for their versatility, high speed, and long lift capabilities. They are especially suitable for high-rise constructions and in industries where loads need to be lifted over significant heights.

In the aviation industry, telfers have been instrumental in managing materials, especially in cargo planes. One of the largest military aircraft in the world, the Lockheed C-5 Galaxy, employs onboard telfers to assist with cargo handling. These telfers move along a rail system installed within the aircraft, allowing for the effortless movement and positioning of goods.

The Boeing 747, another key player in the aviation industry, utilizes telfers in its cargo variant, the Boeing 747-400F. This aids in effective cargo management, enabling the handling of significant quantities of goods with relative ease.

Preliminary assessment and analysis of the experience shows expected reduction of the loading time up to the 30%.

The problem of the telpher integration into the aircraft is proposed to be solved by the attachments of the telpher’s rail (I-beam) to the reinforced frames of the fuselage. The distance between the attachment unites has been found to be about 120 inches or about 3 meters.

Main performance characteristics of the telpher have been determined, these are

Cable (Rope) load F = 36kN but in all calculations the load will be 50kN due to safety factor

Circumferential speed of drum V = 0.33 m/c

Life span L_h = 10000 hours.

Length of cable H = 11m.

Type of gear box lubrication – dipping.

Correct selection of the materials and stress analysis ensure structural integrity and reliability of the telpher structure.

3.2 Advantage of the telfer system installation

The incorporation of telfer systems into a cargo aircraft is not without its benefits, and these advantages can be substantial. Here are some of the key benefits:

One of the main advantages of telfers is the operational efficiency they bring. They enable faster loading and unloading of cargo, thus substantially reducing the turnaround time for an aircraft. This efficiency can lead to considerable cost savings and increased revenue for airline operators.

Safety is a paramount concern in any industry, and aviation is no exception. Telfers enhance safety by replacing the manual handling of heavy cargo. This minimizes the risk of accidents and injuries, as heavy lifting is associated with numerous occupational hazards, including musculoskeletal injuries due to overexertion and accidents caused by dropping or mishandling heavy loads.

Telfers are not only efficient and safe, but they're also versatile. They're capable of handling different types and weights of cargo, which offers flexibility in operations. This flexibility is particularly beneficial in the fast-paced aviation industry, where the cargo can vary significantly from one flight to another.

Another notable advantage of telfers is that they reduce the need for human labor. By automating the loading and unloading process, telfers decrease the number of ground staff needed, which can result in substantial cost savings in human resources.

3.3 Calculation of the telfer parameters

For the durability certification of the hoist engine, it's crucial to meet the overload performance requirements. In terms of overload resistance, the static test load can be increased to simulate the dynamic response during an overload condition, i.e., the engine and the tensioning device must withstand five thousand kilograms.

$$P = \frac{F \cdot V}{1000 \cdot \eta_p} = \frac{50000 \cdot 0.33}{1000 \cdot 0.87} = 7.17 \text{ Kw}$$

where, P_m - power of motor, Kw;

η_p - gear box efficiency factor;

$$\eta_p = \eta_m^2 \cdot \eta_b^3 \cdot \eta_g^2 \cdot \eta_o = 0.98^2 \cdot 0.99^2 \cdot 0.98^2 \cdot 0.98 = 0.87$$

where, $\eta_m = 0.98$ - coupling efficiency factor,

$\eta_b = 0.99$ - bearing efficiency factor,

$\eta_g = 0.98$ - gear efficiency factor,

$\eta_o = 0.98$ - oil mixture efficiency factor;

Frequency of the magnetic field produced by the motor stator, 1/min:

$$n = \frac{60f}{p} = \frac{60 \cdot 4000}{4} = 6000 \text{ Hz.}$$

where, p - number of motor pole pairs,

f - frequency of current, Hz.

Motor of 7,5 Kw is selected.

Frequency of spinning with sliding accounting,

$$n_m = 5720 \frac{1}{\min}.$$

Calculation of fracture force and determination of drum diameter**.**

Cable (rope) fracture force with margin coefficient $k = 6$.

$$F_{rup} = kF = 6 \cdot 25000 = 150000 \text{ N}$$

Steel rope standard ДСТУ 7665-80 with ultimate stress 180 kg-force/mm2 is selected.

Rated fracture force of all wires in cable,

$$F_{rup} = 204000 \text{ N.}$$

Cable diameter,

$$d_{cab} = 17.5 mm.$$

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Drum diameter of the winch,

$$D_{dr} = (20...25) \cdot d_{cab} = (20...25) \cdot 17.5 = 350...437.5\text{mm}$$

Adopt $D_{dr} = 437.5mm$.

Drum rotation frequency, 1/min:

$$n_{dr} = \frac{60 \cdot V}{\pi \cdot D_{dr}} = \frac{60 \cdot 0.33}{3.14 \cdot 0.437} = 14.4$$

Actual gear ratio,:

$$u = \frac{n_m}{n_{dr}} = \frac{5720}{14.4} = 397.2.$$

Gear ratios of stages,

$$u = u_{12} \cdot u_{34} \cdot u_{56} = 7.34 \cdot 7.34 \cdot 7.37 = 397.2$$

where u_{12} - gear ratio of first stage;

u_{34} - gear ratio of second stage;

u_{56} - gear ratio of third stage.

Scheme of telfer is on Fig. 3.1.

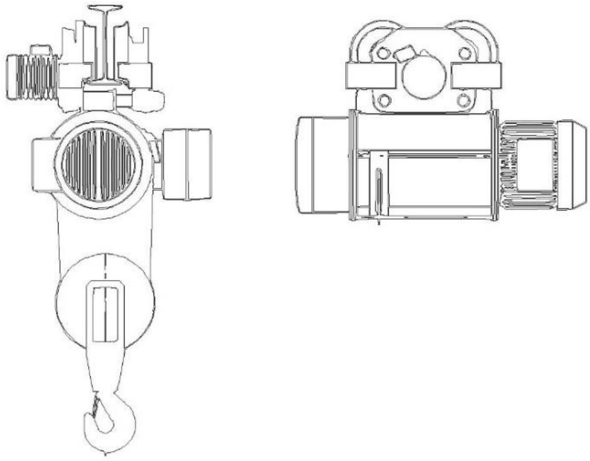


Fig. 3.1. Scheme of telfer.

To calculate a simply supported beam with a section selection, we need to perform the following steps:

Convert all units from inches to meters.

Determine the maximum moment that occurs in the beam.

Select an I-beam such that the maximum moment does not exceed the moment of resistance of the I-beam.

Calculate the deflection of the beam.

The length of the beam in inches is 120 inch because the distance between frames of the fuselage is 20 inch. So distance in 5 frames between points of connection was chosen to get allowable deflection of the beam value.

Conversion of units from inches to meters. 1 inch equals 0.0254 meter, so the length of the beam in meters will be

$$120 \cdot 0.0254 = 3.048 \text{ m}.$$

In diagrams Fig.3.2 and Fig.3.3 shown value of shear force and maximum moment.

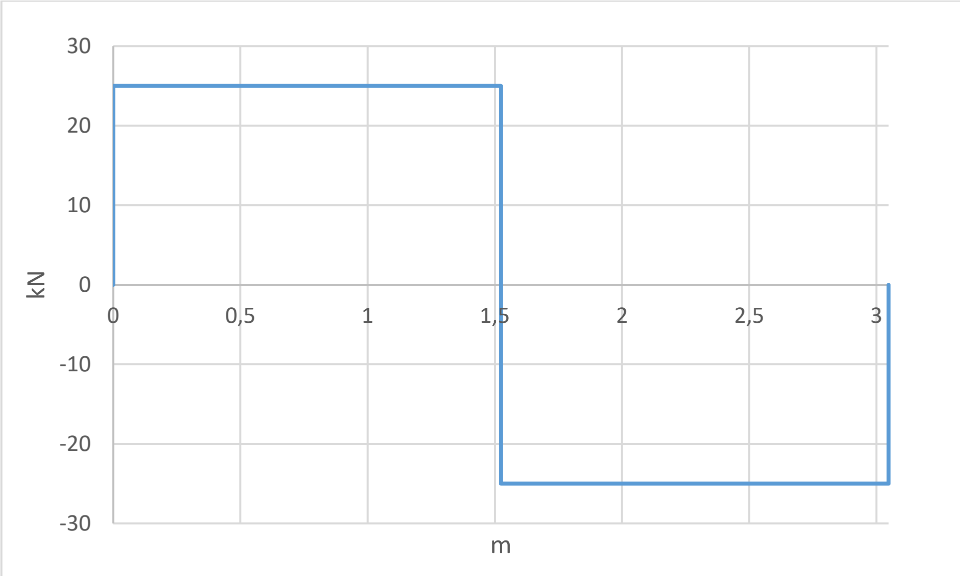


Fig. 3.2. The diagram of shear force

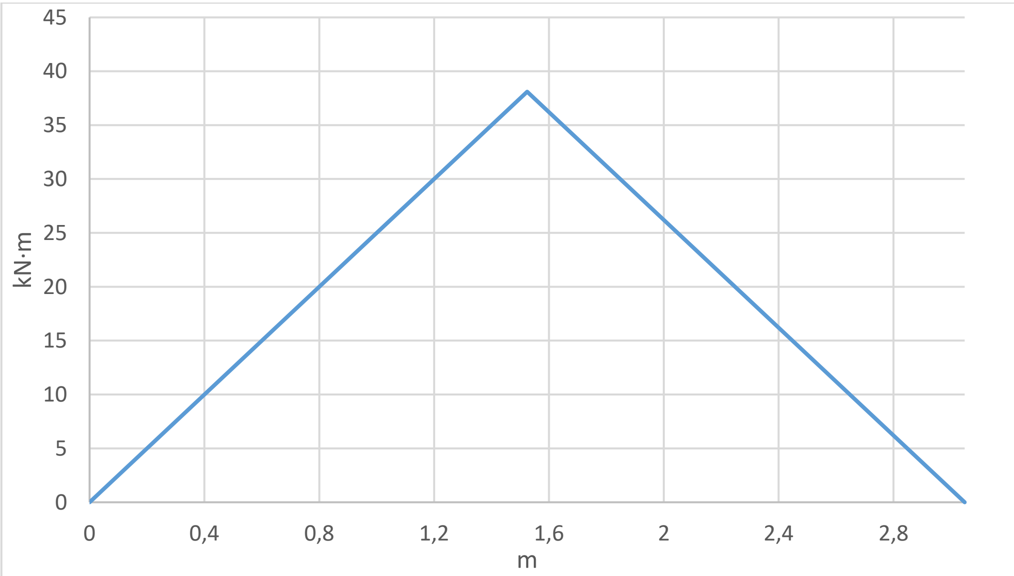


Fig. 3.3. The diagram of maximum moment

Determination of the maximum moment. The maximum moment in the beam occurs at the point of application of the load and can be calculated using the formula

$$M_{max} = \frac{P \cdot L}{4} ,$$

where P is the load (50 kN),

L is the length of the beam (3.048 m).

Thus,

$$M_{max} = \frac{50 \cdot 3.048}{4} = 38.1 \text{ kN} \cdot \text{m}.$$

Selection of the I-beam. For this, we need to know the elastic section modulus of the I-beam, which can be calculated using the formula:

$$W = \frac{I}{y},$$

where I - the moment of inertia of the section, y - the distance from the neutral axis to the extreme point of the section.

The moment of inertia I and the distance y depend on the geometry of the I-beam and can be found in tables for different types of I-beams. We should select such an I-beam that its elastic section modulus W is equal to or greater than the maximum moment M_{max}, and also that the maximum stress in the material does not exceed its yield limit. The maximum stress can be calculated using the formula:

$$\sigma = \frac{M_{max}}{W},$$

where σ - the stress,
M_{max} - the maximum moment,
W - the elastic section modulus of the I-beam

The yield limit for 2024T3 aluminum is approximately 324 MPa.

To select the I-beam, we need to know its geometric characteristics, such as the moment of inertia I and the distance y. This data can be found in manufacturers' catalogs or in specialized handbooks. The height of the I-beam should be around 0.18 meters to connect properly with other telfer elements . Now, let's calculate the required moment of inertia.

The moment of inertia required to support the given load can be calculated using the formula

$$I = \frac{M_{max} \cdot y}{\sigma},$$

where M_{max} - the maximum moment,

y - the distance from the neutral axis to the extreme point of the section (half the height of the I-beam, 0.09 m),

σ - the yield strength of the material .

Value of the yield limit for 2024-T3 aluminum is around 324 MPa.

The moment of inertia of the I-beam section required to support the given load is approximately

$$\frac{8.1 \cdot 0.09\ m}{324} = 1.06 \cdot 10^{-5} \text{m}^4 = 1060 \text{cm}^4$$

This means that is needed to select an I-beam whose moment of inertia of the section equals or exceeds this value in order for it to be able to withstand the given load without deformation exceeding the yield limit of the material.

Beam ДСТУ-8768-2018 №18 is selected.

Calculation of the deflection.

After selecting the I-beam, the deflection of the beam can be calculated by using the formula:

$$\delta = \frac{P \cdot L^3}{48 \cdot E \cdot I},$$

where δ - the deflection,

P - the load,

L - the length of the beam,

E - the modulus of elasticity,

I - the moment of inertia of the I-beam section.

Modulus of elasticity for 2024T3 aluminum it is approximately 73.1 GPa.

$$\delta = \frac{50000 \cdot 3.048^3}{48 \cdot 73.1 \cdot 10^6 \cdot 2.45 \cdot 10^{(-5)}} \approx 6.9\text{mm}.$$

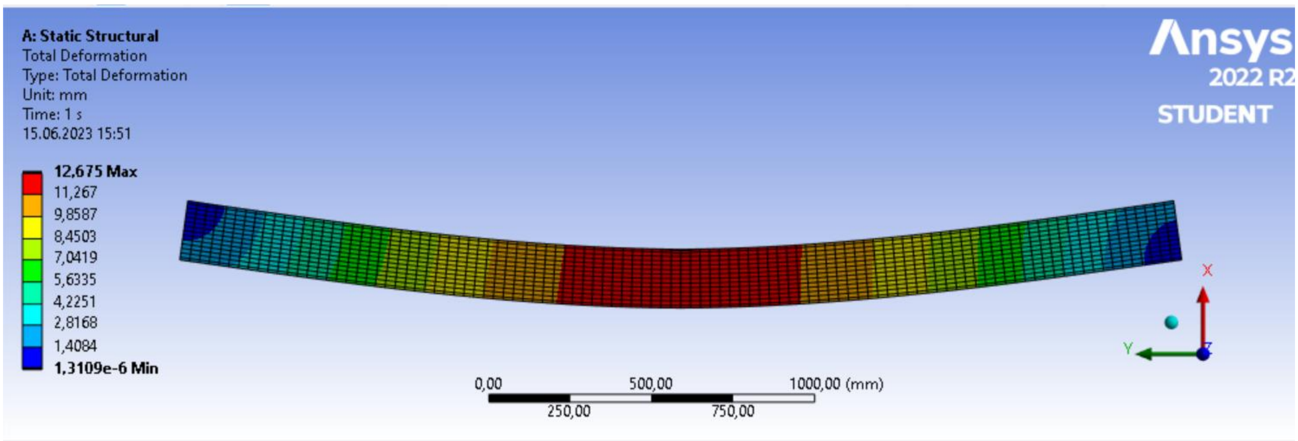
The verification of computations was undertaken through the simulation of a loaded beam in Ansys. Ansys, a world-renowned engineering simulation software, provides an excellent platform to examine the behavior of physical systems under load.

The simulation process involved the creation of a model that mimicked the physical properties of the actual beam, including the material properties, cross-sectional dimensions, and boundary conditions. The external load, corresponding to the load that the beam would carry in its actual usage, was then applied.

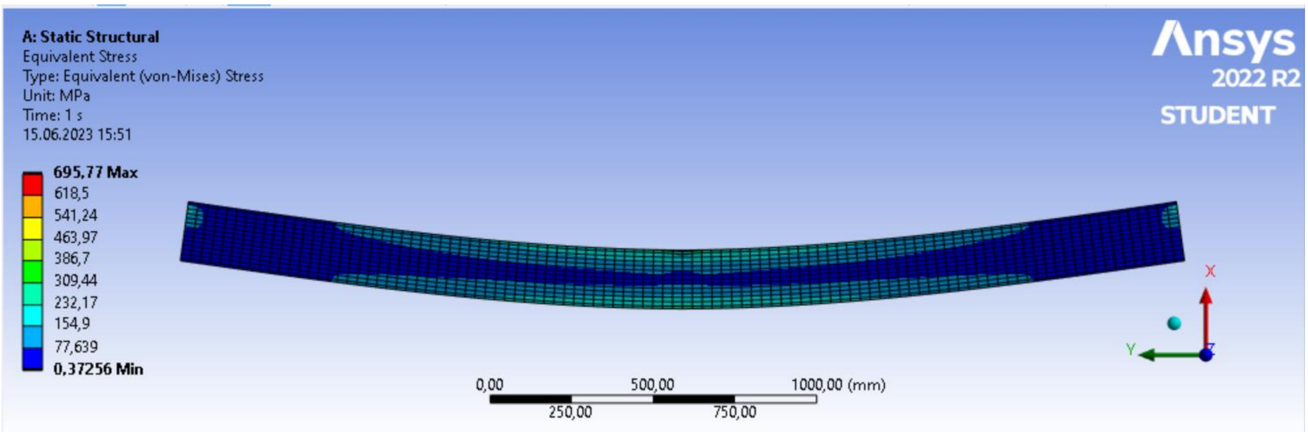
Through this simulation, it was possible to assess the deformation and stress distribution in the beam under the specified loading conditions. The results not only confirmed the accuracy of the initial calculations but also provided valuable visualizations of stress concentrations and deformation patterns. This further contributed to the understanding of the beam's performance under load, informing any necessary design adjustments.

Thus, the simulation of a loaded beam in Ansys proved to be an essential tool in verifying the accuracy of the calculations and gaining a more comprehensive understanding of the behavior of the beam under load. It demonstrated the value of such advanced simulation tools in enhancing the reliability and safety of structural design.

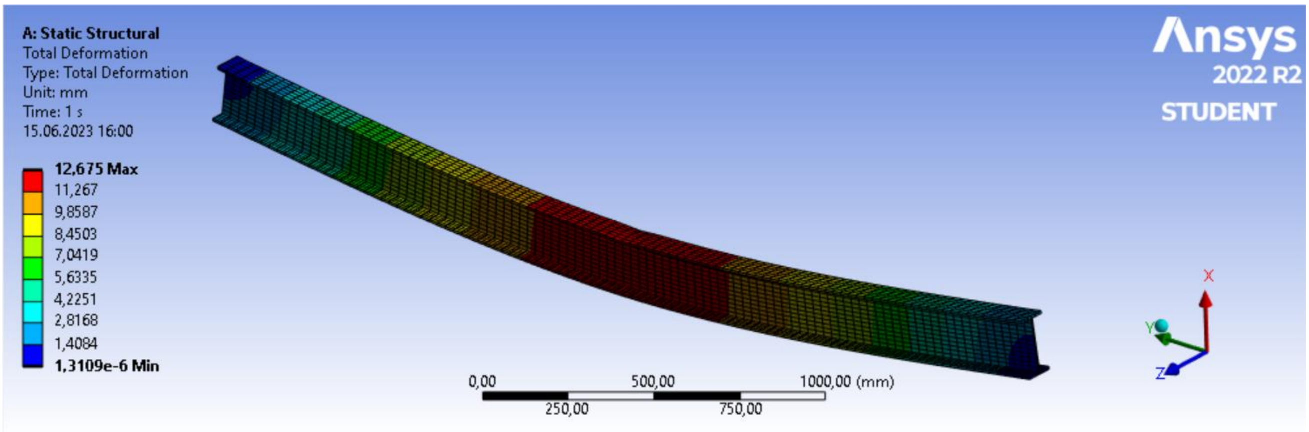
Results of simulation shown on the Fig.3.4., on the Fig. 3.5. and on the Fig.3.6.



The Fig. 3.4.



The Fig. 3.5



The Fig. 3.6.

Conclusion to the special part

In conclusion, incorporating telfer systems into cargo aircraft significantly enhances operational efficiency, safety, versatility, and workforce management in the aviation industry. The use of telfers not only quickens the loading and unloading of cargo, reducing the turnaround time for aircraft, but also leads to potential cost savings and increased revenue for airline operators.

In terms of safety, telfers reduce the risk of accidents and injuries associated with manual handling of heavy cargo, demonstrating their critical role in ensuring safer working conditions in aviation and various other industries. Their versatility further extends their utility by enabling the handling of various types and weights of cargo, which is crucial given the dynamic nature of cargo content in aviation.

Lastly, the use of telfers can lead to reduced manpower requirements as they automate the loading and unloading process. This reduction of the need for human labor can translate into significant cost savings in human resources.

The deployment of telfers in cargo aircraft represents a significant stride in operational efficiency, safety, versatility, and labor management. Their substantial benefits make them an indispensable asset in the aviation industry and beyond. As we continue to innovate and enhance these systems, it is anticipated that their contribution to industrial operations will further increase, paving the way for more streamlined, safe, and cost-effective cargo handling processes.

GENERAL CONCLUSIONS

The subsequent points highlight the results of my design efforts:

- Preliminary design of long range freighter with improved overhead loading equipment;
- cabin layout of a long-range cargo aircraft with 90 ton payload;
- calculations of the airplane's center of gravity;
- calculations of the landing gear's key geometrical parameters;
- choice of wheels that meet the requirements.

The aircraft designed meets its intended purpose, with its geometric properties ensuring the required aerodynamic performance, thereby facilitating efficient operation.

In the specialized section, a telfer system was designed, offering:

- increase of operational efficiency;
- increace safety;
- gives flexibility in load process;
- reduced manpower;
- meet all the aviation requirements and standards.

REFERENCES

1. PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES, United States Department of Transportation https://www.ecfr.gov/current/title-14/chapter-I/subchapter-C/part-25
2. Easy Access Rules for Large Aeroplanes (CS-25), European Union Aviation Safety Agency https://www.easa.europa.eu/en/document-library/easy-access-rules/easy-access-rules-large-aeroplanes-cs-25
3. Hoisting and Mounting the Aircraft Engine for Installation https://www.aircraftsystemstech.com/p/hoisting-and-mounting-engine-for.html
4. Boeing Commercial Airplanes (2021). 777 Freighter. Boeing Official Website. Retrieved June 14, 2023, from https://www.boeing.com/commercial/777/
5. The Hoist and Winch Group (2021). The Role of Hoists in Aircraft Manufacturing. Hoist and Winch Official Website. Retrieved June 14, 2023, from https://www.hoistandwinch.co.uk
6. Коефіцієнт – навантаження. Технічна енциклопедія TechTrend. https://techtrend.com.ua/index.php?newsid=26003034
7. Принцип роботи й особливості електричного таля (тельфера). https://www.6262.com.ua/news/2967675/princip-roboti-j-osoblivosti-elektricnogo-tala-telfera
8. The Brush Electric Hoist, SCIENCE journal. https://www.science.org/doi/10.1126/science.ns-14.345.175
9. Arne Thesen, Lei Lei. An expert scheduling system for material handling hoists. Journal of Manufacturing Systems Volume 9, Issue 3, 1990, Pages 247-252 https://www.sciencedirect.com/science/article/abs/pii/027861259090055M

Appendix A

REQUEST FOR CALCULATION WORK

Student Yurchyk Denys Instructor Maslak Tetyana Petrivna

ADMITTED TO CALCULATION... (Data, Instructor's Signature)

МАКСИМАЛЬНОЕ ЧИСЛО ПАССАЖИРОВ **N** =..-------. ИЛИ МАКСИМАЛЬНАЯ МАССА ГРУЗА …90000..**kg**;
Passenger Number or Maximum Payload

КОЭФФИЦИЕНТ ДОПОЛНИТЕЛЬНОЙ ЗАГРУЗКИ **K1**=.1,1.; МАССА БЕЗПЛАТНОГО БАГАЖА **М.ББ** =.---------.**kg**;
Extra Load Factor Passenger Baggage

ЧИСЛО ЧЛЕНОВ ЭКИПАЖА **Ncrew** =2; РЕИСОВОЕ ВРЕМЯ ПОЛЕТА С МАС. ГРУЗОМ **T** = 11.5 **hours**;
Flight Crew Number Block Time with Maximum Payload

КОЛИЧЕСТВО БОРТПРОВОДНИКОВ **N** =.......... ИЛИ СОПРОВОЖДАЮЩИХ **N** =.4.;
Attendant Number or Load Master Number

ОТНОСИТЕЛЬНАЯ МАССА МАКСИМАЛЬНОЙ КОММЕРЧЕСКОЙ НАГРУЗКИ 0,29.;
Payload Fraction

ОТНОСИТЕЛЬНАЯ МАССА ТОПЛИВА ПРИ ПОЛЕТЕ С МАКСИМАЛЬНОЙ КОММЕРЧЕСКОЙ НАГРУЗКОЙ 0,31.;
Fuel Fraction under Maximum Payload

ЭНЕРГОВООРУЖЕННОСТЬ САМОЛЕТА. 0,281.**kW/kg** ИЛИ ТЯГОВООРУЖЕННОСТЬ САМОЛЕТА.............**N/kg**;
Power-to-mass Ratio or Thrust-to-mass Ratio

КОЛИЧЕСТВО ОСНОВНЫХ ДВИГАТЕЛЕИ 2; КОЛИЧЕСТВО РЕВЕРСИРУЕМЫХ ДВИГАТЕЛЕЙ 2.;
Engine Number Engine Number Reversed

ДАЛЬНОСТЬ ПОЛЕТА С МАКСИМАЛЬНОЙ КОММЕРЧЕСКОЙ НАГРУЗКОЙ **L**=10047.**km**;
Flight Range with Maximum Payload

ВЫСОТА НАЧАЛА КРЕИСЕРСКОГО ПОЛЕТА 11,5 **km**; КРЕИСЕРСКАЯ ЭКОНОМИЧЕСКАЯ СКОРОСТЬ 905.**km/h**;
Cruise Altitude Cruise Speed

СТРЕЛОВИДНОСТЬ КРЫЛА ПО 0.25 ХОРД В ГРАД. 31.64 ; СРЕДНЯЯ ОТН. ТОЛЩИНА КРЫЛА ………. (в долях);
Sweep Angle on One Quarter Line Mean Thickness Ratio (in fractions)

УДЛИНЕНИЕ КРЫЛА ПО ПОЛНОИ ПЛОЩАДИ . 8.68.; СУЖЕНИЕ КРЫЛА ПО ПОЛНОЙ ПЛОЩАДИ 6,71.;
Aspect ratio for Total Wing Area Taper Ratio for Total Wing Area

ТИП АЭРОДИНАМИЧЕСКОГО ПРОФИЛЯ КРЫЛА supercritical ЗАКОНЦОВКИ "УИТКОМБА" no (применяются или нет);
Airfoil Type Winglets (used or not)

ОТНОСИТЕЛЬНАЯ ПЛОЩАДЬ ПРИКОРНЕВЫХ НАПЛЫВОВ КРЫЛА (в долях)0.01.;
Relative Area of Wing Extensions (in fractions)

УСТАНОВЛЕНЫ НА КРЫЛЕ СПОЙЛЕРЫ ИЛИ ИНТЕЦЕРТОРЫ (да или нет) yes.;
Spoilers used (yes or no)

МАКСИМАЛЬНЫЙ ЭКВИВАЛЕНТНЫЙ ДИАМЕТР ФЮЗЕЛЯЖА. 6.20..**m**; УДЛИНЕНИЕ ФЮЗЕЛЯЖА 10.13;
Fuselage Maximum Equivalent Diameter Fuselage Fineness Ratio

СУММА УДЛИНЕНИЙ НОСОВОЙ И ХВОСТОВОЙ ЧАСТЕЙ ФЮЗЕЛЯЖА. 10,42.;
Sum of Fineness Ratios for Forward and Aft Fuselage Parts

МИНИМАЛЬНАЯ (**техническая**) ПОСАДОЧНАЯ СКОРОСТЬ **Vmin.** = 252.6.**km/h**;
Minimal Landing Speed

СТЕПЕНЬ МЕХАНИЗИРОВАННОСТИ КРЫЛА . seven slats and a Krueger flap (указать индексом по МУ);
High-lift Device Coefficient (index from Methodological Guide)

СТЕПЕНЬ ПОВЫШЕНИЯ ДАВЛЕНИЯ ДВИГАТЕЛЯ 39,3; СТЕПЕНЬ ДВУХКОНТУРНОСТИ ДВИГАТЕЛЯ 8,14.;
Engine Pressure Ratio Engine By-pass Ratio

ДЛИНА ЛЕТНОЙ ПОЛОСЫ АЭРОДРОМА БАЗИРОВАНИЯ (ВПП + КПБ) 2990**km**;
Field Length Available (Runway + Stopway)

МАКСИМАЛЬНАЯ ВЫСОТА КРЕЙСЕРСКОГО ПОЛЕТА (практический потолок) **Hcr.max**. = . 13,14**km**;
Maximum Cruise Altitude (Flight Ceiling)

УГОЛ СТРЕЛОВИДНОСТИ ГОРИЗОНТАЛЬНОГО ОПЕРЕНИЯ В ГРАДУСАХ 35.00 ;
Horizontal Tail Sweep Angle (in degrees)

УГОЛ СТРЕЛОВИДНОСТИ ВЕРТИКАЛЬНОГО ОПЕРЕНИЯ В ГРАДУСАХ 46.00;
Vertical Tail Sweep Angle (in degrees)

СУММА НЕУЧТЕННЫХ МАСС 100 **kg**. (*массы нетипичных систем и механизмов, дополнительные массы для оборудования салонов экстра класса, массы систем диагностики и встроенного контроля оборудования и основных систем самолета).*
Weights for Additional Equipment (equipment for high class passenger cabins)

Appendix B

INITIAL DATA AND SELECTED PARAMETERS

I. Passenger Number	0
II. Flight Crew Number	2
Flight Attendant or Load Master Number	4
Mass of Operational Items	1812,79 kg.
Payload Mass	90000,0 kg.
Cruising Speed	895km/h
Cruising Mach Number	0.8412
Design Altitude	11.5km
Flight Range with Maximum Payload	9500km
Runway Length for the Base Aerodrome	3.3km
Engine Number	2
Thrust-to-weight Ratio in N/kg	2.8
Pressure Ratio	39.3
Assumed Bypass Ratio	8.14
Optimal Bypass Ratio	4.5
Fuel-to-weight Ratio	0.31
Aspect Ratio	8.0
Taper Ratio	5.0
Mean Thickness Ratio	0.1
Wing Sweepback at Quarter Chord	33.0 degree
High-lift Device Coefficient	1.16
Relative Area of Wing Extensions	0.01

Wing Airfoil Type-supercritical
Winglets- no
Spoilers- yes

Fuselage Diameter	6.2m
Finess Ratio	10.13
Horizontal Tail Sweep Angle	35.0degree
Vertical Tail Sweep Angle	46.0 degree

III. CALCULATION RESULTS

IV. Optimal Lift Coefficient in the Design Cruising Flight Point Cy 0.48291

Induce Drag Coefficient Cx 0.00877

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

V. Cruising Mach Number	Mcruise	0.8412
Wave Drag Mach Number	Mcrit	0.85407
Calculated Parameter	Dm	0.01288

Wing Loading in kPa (for Gross Wing Area):

At Takeoff	6.222
At Middle of Cruising Flight	5.032
At the Beginning of Cruising Flight	5.997

Drag Coefficient of the Fuselage and Nacelles	0.00681
Drag Coefficient of the Wing and Tail Unit	0.0088

Drag Coefficient of the Airplane:

At the Beginning of Cruising Flight	0.02664
At Middle of Cruising Flight	0.02496
Mean Lift Coefficient for the Ceiling Flight	0.48291
Mean Lift-to-drag Ratio	19.34637
Landing Lift Coefficient	1.575

Landing Lift Coefficient (at Stall Speed)	2.363
Takeoff Lift Coefficient (at Stall Speed)	1.925
Lift-off Lift Coefficient	1.405
Thrust-to-weight Ratio at the Beginning of Cruising Flight	0.463
Start Thrust-to-weight Ratio for Cruising Flight	2.141
Start Thrust-to-weight Ratio for Safe Takeoff	2.860

Design Thrust-to-weight Ratio R0 2.975

Ratio $D_r = R_{cruise} / R_{takeoff}$ Dr 0.749

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

Takeoff	30.0352
Cruising Flight	56.4638
Mean cruising for Given Range	67.2668

FUEL WEIGHT FRACTIONS:

VI.

Fuel Reserve	0.03129
Block Fuel	0.33362

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.09893
Horizontal Tail	0.00857
Vertical Tail	0.00892
Landing Gear	0.03533
Power Plant	0.09323
Fuselage	0.06695
Equipment and Flight Control	0.09169
Additional Equipment	0.00283
Operational Items	0.00452
Fuel	0.36492
Payload	0.22417

Airplane Takeoff Weight	401475kg
Takeoff Thrust Required of the Engine	597.14 kN

Air Conditioning and Anti-icing Equipment Weight Fraction	0.0096
Passenger Equipment Weight Fraction (or Cargo Cabin Equipment)	0.0001
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.0035
Furnishing Equipment Weight Fraction	0.0425
Flight Control Weight Fraction	0.0027
Hydraulic System Weight Fraction	0.0088
Electrical Equipment Weight Fraction	0.0091
Radar Weight Fraction	0.0030
Navigation Equipment Weight Fraction	0.0045
Radio Communication Equipment Weight Fraction	0.0023
Instrument Equipment Weight Fraction	0.0053
Fuel System Weight Fraction	0.0127

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)	0.0028

VII. TAKEOFF DISTANCE PARAMETERS

VIII. Airplane Lift-off Speed	302.88 km/h
Acceleration during Takeoff Run	2.32 m/s*s
Airplane Takeoff Run Distance	1523 m
Airborne Takeoff Distance	578 m
Takeoff Distance	2101 m

IX. CONTINUED TAKEOFF DISTANCE PARAMETERS

X. Decision Speed	287.74 km/h
Mean Acceleration for Continued Takeoff on Wet Runway	0.3 m/s
Takeoff Run Distance for Continued Takeoff on Wet Runway	2508.96 m
Continued Takeoff Distance	3087.33 m
Runway Length Required for Rejected Takeoff	3198.33 m

XI. LANDING DISTANCE PARAMETERS

XII. Airplane Maximum Landing Weight	286891 kg
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight	21.3 min
Descent Distance	52.94 km
Approach Speed	260.05 km/h
Mean Vertical Speed	2.08 m/sec
Airborne Landing Distance	521 m
Landing Speed	245.05 km/h
Landing run distance	795 m
Landing Distance	1316 m
Runway Length Required for Regular Aerodrome	2197 m
Runway Length Required for Alternate Aerodrome	1868 m

XIII. ECONOMICAL EFFICIENCY

XIV. **THESE PARAMETERS ARE NOT USED IN THE PROJECT**