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

ДОПУСТИТИ ДО ЗАХИСТУ
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«___» ____________ 2024 р.

КВАЛІФІКАЦІЙНА РОБОТА
ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ
«БАКАЛАВР»

Тема: «Електричний тельфер вантажного середньо-магістрального літака»

Виконав: __________ **Дмитро СУЛЯВА**

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

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

Київ 2024

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

PERMISSION TO DEFEND
Head of the department,
Associate Professor, PhD.
______ Sviatoslav YUTSKEVYCH
"___" ____________ 2024

BACHELOR DEGREE THESIS

Topic: "Electrical hoist for the mid range cargo plane"

Fulfilled by: ____________ **Dmytro SULIAVA**

Supervisor:
Doctor of Sc., professor ____________ **Mykhailo KARUSKEVYCH**

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

Kyiv 2024

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, к.т.н., доцент
________ Святослав ЮЦКЕВИЧ
«___» ____________ 2024 р.

ЗАВДАННЯ

на виконання кваліфікаційної роботи здобувача вищої освіти

СУЛЯВИ ДМИТРА ЮРІЙОВИЧА

1. Тема роботи: «Електричний тельфер вантажного середньо-магістрального літака», затверджена наказом ректора від 15 травня 2024 року № 794/ст.

2. Термін виконання роботи: з 20 травня 2024 р. по 16 червня 2024 р.

3. Вихідні дані до роботи: маса комерційного навантаження 80000 кг, дальність польоту з максимальним комерційним навантаженням 4100 км, крейсерська швидкість польоту 850 км/год, висота польоту 11 км.

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 грузової кабіни, розрахунок центрування літака, спеціальна частина, яка містить аналіз електричного тельфера, визначення потужності його мотору, розрахунок на міцність крюка та грузової балки

5. Перелік обов'язкового графічного (ілюстративного) матеріалу: загальний вигляд літака (А1×1), компонувальне креслення фюзеляжу (А1×1), модель і діаграми ANSYS, презентація PowerPoint з результатами виконання кваліфікаційної роботи.

6. Календарний план-графік:

№	Завдання	Термін виконання	Відмітка про виконання
1	Вибір вихідних даних, аналіз льотно-технічних характеристик літаків-прототипів.	20.05.2024 – 21.05.2024	
2	Вибір та розрахунок параметрів проектованого літака.	22.05.2024 – 23.05.2024	
3	Виконання компонування літака та розрахунок його центрування.	24.05.2024 – 25.05.2024	
4	Розробка креслень по основній частині дипломної роботи.	26.05.2024 – 27.05.2024	
5	Огляд літератури за проблематикою роботи, аналіз застосування електричних тельферів.	28.05.2024 – 29.05.2024	
6	3D моделювання грузової балки і розрахунок гака на міцність.	30.05.2024 – 31.05.2024	
7	Оформлення пояснювальної записки та графічної частини роботи.	01.06.2024 – 02.06.2024	
8	Подача роботи для перевірки на плагіат.	03.06.2024 – 06.06.2024	
9	Попередній захист кваліфікаційної роботи.	07.06.2024	
10	Виправлення зауважень. Підготовка супровідних документів та презентації доповіді.	08.06.2024 – 10.06.2024	
11	Захист дипломної роботи.	11.06.2024 – 16.06.2024	

7. Дата видачі завдання: 20 травня 2024 року

Керівник кваліфікаційної роботи ____________ Михайло КАРУСКЕВИЧ

Завдання прийняв до виконання ____________ Дмитро СУЛЯВА

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,
Associate Professor, PhD.
____ Sviatoslav YUTSKEVYCH
"___" ____________ 2024

TASK

for the bachelor degree thesis

Dmytro SULIAVA

1. Topic: "Electrical hoist for the mid range cargo plane", approved by the Rector's order № 794/ст from 15 May 2024.
2. Period of work: since 20 May 2024 till 16 June 2024.
3. Initial data: payload 80000 kg, flight range with maximum capacity 4100 km, cruise speed 850 km/h, flight altitude 11 km.
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, a special part that contains an analysis of an electric hoist, determination of the power of its motor, calculation of the strength of the hook and cargo beam.
5. Required material: general view of the airplane (A1×1), layout of the airplane (A1×1), ANSYS model and diagrams, PowerPoint presentation of the work results.

6. Thesis schedule:

№	Task	Time limits	Done
1	Selection of initial data, analysis of flight technical characteristics of prototypes aircrafts.	20.05.2024 – 21.05.2024	
2	Selection and calculation of the aircraft designed parameters.	22.05.2024 – 23.05.2024	
3	Performing of aircraft layout and centering calculation.	24.05.2024 – 25.05.2024	
4	Development of drawings on the thesis main part.	26.05.2024 – 27.05.2024	
5	Review of the literature, analysis of the use of electric hoists	28.05.2024 – 29.05.2024	
6	3D modeling of the cargo beam and calculation of the strength of the hook.	30.05.2024 – 31.05.2024	
7	Explanatory note checking, editing, preparation of the diploma work graphic part.	01.06.2024 – 02.06.2024	
8	Submission of the work to plagiarism check.	03.06.2024 – 06.06.2024	
9	Preliminary defense of the thesis.	07.06.2024	
10	Making corrections, preparation of documentation and presentation.	08.06.2024 – 10.06.2024	
11	Defense of the diploma work.	11.06.2024 – 16.06.2024	

7. Date of the task issue: 20 May 2024

Supervisor: ____________ Mykhailo KARUSKEVYCH

Student: ____________ Dmytro SULIAVA

РЕФЕРАТ

Пояснювальна записка кваліфікаційної роботи бакалавра «Електричний тельфер вантажного середньо-магістрального літака»:

57 с., 10 рис., 10 табл., 14 джерел

Дана кваліфікаційна робота присвячена розробці аванпроєкту вантажного середньомагістрального літака з можливістю транспортування негабаритних вантажів, що відповідає міжнародним стандартам польотів, нормам безпеки, економічності та надійності, удосконаленого додатковим завантажувальним обладнанням.

В роботі було використано методи аналітичного розрахунку, компьютерного проєктування за допомогою CAD/CAM/CAE систем, чисельного моделювання і розрахунку на міцність гака та грузової балки.

Практичне значення результату кваліфікаційної роботи полягає в установленні електричного тельфера, що полегшує та пришвидшує завантаження та розвантаження літака

Матеріали кваліфікаційної роботи можуть бути використані в навчальному процесі та в практичній діяльності конструкторів спеціалізованих проектних установ.

Дипломна робота, аванпроект літака, компонування, центрування, електричний тельфер, розрахунок на міцність

ABSTRACT

Bachelor degree thesis "Electrical hoist for the mid range cargo plane"

57 pages, 10 figures, 10 tables, 14 references

This thesis is dedicated to the development of an advance project of a medium-haul cargo plane with the possibility of transporting oversized cargo, which meets international flight standards, safety, economy and reliability standards, improved by additional loading equipment.

The design methodology is based on prototype analysis to select the most advanced technical decisions, engineering calculations to get the technical data of designed aircraft and computer based design using CAD/CAM/CAE systems. In special part the numerical modeling and calculation of the strength of the hook and cargo beam.

Practical value of the work is substantiation of the possibility to install electric hoist, which facilitates and speeds up the loading and unloading of the aircraft.

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

Bachelor thesis, preliminary design, cabin layout, center of gravity calculation, electric hoist, strength calculation

Format	№	Designation	Name	Quantity	Notes
			<u>General documents</u>		
A4	1	NAU 24 06S 00 00 00 14 TW	Task for work	1	
	2	NAU 24 06S 00 00 00 14	Long-range passenger aircraft	2	
A1		Sheet 1	General view	1	
A1		Sheet 2	Fuselage layout	1	
A4	3	NAU 24 06S 00 00 00 14 EN	Medium-range cargo aircraft	57	
			Explanatory note		
			<u>Documentation for assembly units</u>		
A1	4	NAU 24 06S 00 00 00 14	Design of electrical hoist	1	

	Sh.	№ doc.	Sign	Date
Done by	Suliava D.Y			
Supervisor	Karuskevych M.V			
St.control.	Krasnopolskyi V.S.			
Head of dep.	Yutskevych S.S.			

NAU 24 06S 00 00 00 14 EN

Preliminary design of cargo aircraft with electrical hoist (List of qualification paper)

list	sheet	sheets
Q	9	57

404 ASF 134

CONTENT

LIST OF ABBREVIATIONS

MAC – Mean aerodynamic chord

C.G – Center of gravity

LG – Landing gear

US – United States

MTOW – Maximum takeoff weight

TU – Tail unit

HTU – Horizontal tail unit

VTU – Vertical tail unit

INTRODUCTION

Undoubtedly, the invention and development of aviation made a great contribution to the development of passenger and cargo transportation, military and research fields. According to aviation history, the first practical demonstration of air freight occurred in November 1910, when a cargo of silk was flown from Dayton to Columbus. From that moment on, air transport developed steadily. Air transport has become a mode of transport widely used by a wide range of industries and companies. Air freight is becoming an increasingly better alternative for shipping goods quickly and safely. Today, the carrying capacity, practicality, speed, safety, availability and economy of aircraft have increased significantly, allowing businesses to move goods quickly and efficiently over long distances, ensuring timely delivery and access to markets around the world. Thanks to this, air transport accounts for 35% of world trade at a value of 6.8 trillion US dollars per year. Therefore, air freight is an important aspect of modern logistics and plays an important role in the global economy.

Aircraft cargo can be categorized into different types based on the nature of the goods being transported and the specific requirements of the cargo. Here are some common types of aircraft cargo:

1. General cargo. As the foundation of the air transportation industry, general cargo is a generally important category. These goods are generally non-perishable and can include a variety of items such as cars, electronics, clothing, consumer goods, etc.

2. Special cargo. Special cargo is goods that have special requirements for handling, storage or transportation. This category includes a wide range of items such as art, pharmaceuticals and sensitive devices.

3. Live animals. Aircraft are often used to transport live animals, including livestock and pets. Specialized containers and conditions are provided to ensure the well-being of the animals during transport.

4. Dangerous goods. Hazardous materials such as chemicals, explosives, and flammable substances that require special handling and compliance with strict safety regulations.

5. Oversized and Heavy Cargo. Some goods are very heavy or very large and therefore cannot be transported on most cargo aircraft. They require a specialized supply chain, including special aircraft with oversized cargo bays and nose or tale cargo ramps, as well as special equipment for handling during loading. This may include oversized machinery, industrial equipment, or other bulky items.

6. Military cargo. Equipment, supplies, and vehicles transported for military purposes. This may include tanks, aircraft parts, shells, weapon or other military-related items.

7. Mail cargo. The Letter Mail segment plays a central role in the global mail and parcel delivery network. It guarantees the punctual delivery of letters, documents and parcels to their destination. Around 328 billion letters and 7.4 billion parcels are handled by air freight every year, making mail freight the largest share of air freight shipments.

Obviously, the process of loading and unloading cargo requires some effort. The aim of the work is to develop an electric hoist for a medium-haul cargo plane, that will help save time and make work much easier and safe for employees.

1. PRELIMINARY DESIGN OF MEDIUM RANGE AIRCRAFT

1.1. Analysis of prototypes and short description of designing aircraft

The task is to create a mid-range multi-purpose military cargo aircraft which does not require big runways, can land on the ground, has big payload and large cargo bay for the transportation of bulky cargo like vehicles or helicopters with a rear ramp for loading and unloading cargo.

To achieve the desired results, we will need a large-area wing with a high-wing position, powerful engines, a chassis capable of withstanding heavy loads, and a long cargo compartment.

Like any other aircraft during the design it must go through the stage of the conceptual design, preliminary design and detail design. To help with this, we will rely on already existing models of aircraft such as the Antonov AN-22, C-17 Globemaster 3 and Airbus A-400M because they have similar technical characteristics.

The prototype on which we will rely most is the C-17, so the new aircraft will have noticeable features of the existing one. The performances of the prototype are given below in table 1.1.

Table 1.1

Operational-technical data of prototypes

PARAMETERS	AIRCRAFTS			
	C-17	AN-22	A-400M	Designed aircraft
1	2	3	4	5
The purpose of airplane	Cargo	Cargo	Cargo	Cargo
Crew/flight attend. persons	2/3	2/3	2/3	2/3
Maximum take-off weight, MTOW, kg	265350	227000	141000	299034

1	2	3	4	5
Most pay-load, mк.max, kg	75000	80000	37000	80000
Passenger's seat	3	5	3	3
The height of the flight, m	13715	9000	11300	11000
Cruise speed of the flight km/h	834	560	780	850
Range mк.max, km	4445	5225	8900	4100
Take off distance, m	1066.8	1300	980	1220
Wing span, m	52	64	42.4	55.48
Number and type of engines	4 × Pratt & Whitney PW2040 turbofans	4 × NK-12MA turboprop	4 x Europrop TP400	4 × Pratt & Whitney PW2040 turbofans
The form of the cross-section fuselage	circular	circular	circular	circular
Fuselage length, m	53	57.84	45.1	57.6
Fuselage diameter, m	6.8 m	6 m	4.1 m	6.86
Fuselage fineness ratio	7.79	9.55	10.97	8.4
Sweepback on 1/4 chord, ^{0}	25	–	15	29

1.2. Brief description of the main parts of the aircraft

The aircraft is high-wing cargo plane capable of rapid strategic delivery of all types of cargo to main operating bases or directly to forward bases in the deployment area. The aircraft's design enables high-angle, steep approaches at relatively slow speeds, allowing it to operate into small, austere airfields and onto runways. Common design methods used in the aviation sector are present in the aircraft

1.2.1. Fuselage

A semi-monocoque fuselage allows maximum space to be gained for the transportation of large elements such as tanks or trucks. Its structure consists frames, which give the aircraft skin its final shape. They are mounted parallel to each other and connected by longerons around the entire circumference of the surface. There are also some bulckheads that separate the different compartments of the aircraft and semi-bulkheads that support hydraulic systems, such as the pistons that open and close the rear doors

1.2.2. Wing

It is a super critical airfoil with two I-shaped spars constructed from the root to the wing tip. In between, about 30 ribs are divided into three sections: the leading edge, which consists of the first quarter of the wing ribs, and movable devices for moving the front flaps. The second section between the two spars is the thickest part of the ribs and is reinforced along the wing by stringers. Finally, the third section presents both mobile and static parts, depending on the point observed; if it is part of the rear flaps, there are no ribs that give it the shape. The aircraft has winglets at the wingtip. Also, the ribs of the wings have holes in their section for various reasons, such as to reduce weight or to facilitate communication between devices operating along the wings

1.2.3. Cockpit

The front part of the aircraft is separated in two floors, the lower one has the pilot’s entrance and the second one contains the cockpit, as well as many electrical instruments and other devices or the landing gear’s front wheel. The cockpit is equipped with all modern and necessary equipment such as 2 fulltime all-function head-up displays (HUD), 4 multi-function active matrix liquid crystal displays, digital electronics for navigational system, Integrated radio management system with communications system open architecture (COSA) and Quadruple-redundant electronic flight control with mechanical backup system. The automatic flight control system is upgraded with BAE Systems' CsLEOS real-time operating system, which is certified for global air traffic management system requirements.

1.2.4. Cargo bay

The cargo is loaded into the aircraft through a large rear door ramp. The advanced cargo system allows all systems to operate on any type of mission. The ramp not only ensures a pressure seal, it provides support for payload in flight, facilitates the material handling of pallets to either of the two rail systems, and withstands cresting forces during the loading of high-footprint vehicles such as tanks, trucks, and bulldozers. The ramp is constructed of four aluminum alloy longitudinal beams terminating at the hinge point and aluminum transverse beams that support an extruded aluminum plank floor. The floor houses tie-down rings, plus rails and rollers for securing pallets and an extraction parachute tow-release mechanism. Also there is located seats for paratroopers or flight engineers.

1.2.5. Landing gear

The plane features a nonsteerable six-wheel-per-side main landing gear that retracts into low-drag gear pods, and a steerable dual-wheel nose gear that retracts into the fuselage. The main landing gear consists of dual struts on each side of the aircraft with three wheels on each strut in a lever suspension arrangement. The fore and aft struts rotate toward each other 90 degrees during retraction, and the inboard wheel on each strut relaxes to an offset position to create a low pod frontal area and reduce drag. The system enables short take-offs and landings almost anywhere in the world.

Conclusion to the analytical part

Based on the flight and technical data of the selected prototypes, a new midrange cargo aircraft with a large cargo compartment and a payload of 80,000 kilograms was created. The C-17 was chosen as the main prototype due to its relative novelty (entered service in July 1993) and popularity in the world (270 aircraft were manufactured and are in service in 8 countries). The aircraft is equipped with modern avionics and automated flight control systems, which increases safety and reduces the workload on the crew. A detailed description of the airplane's structural elements was carried out.

2. AIRCRAFT MAIN PARTS CALCULATIONS

Geometry plays a crucial role in the design, construction, and operation of aircraft. Geometry influences the structural integrity and strength of an aircraft and his flight characteristics. The shape and dimensions of various components such as wings, fuselage, and empennage are determined based on geometric principles to ensure they can withstand aerodynamic forces, structural loads, and vibrations encountered during flight.

The initial data for the calculation of further geometric parameters have been chosen from the APENDIX A, were obtained by using special software developed at the Department of Aeronautical Engineering of the National Aviation University

2.1. Wing geometry calculation

Wing geometry is critical for optimizing aerodynamic performance, lift generation, stability, control, fuel efficiency, maneuverability, and structural integrity of the aircraft. Area of the wing is calculated based on the wing loading and gross weight:

$$S_{wing} = \frac{m_0 \cdot g}{P_0} = \frac{299034 \cdot 9.8}{4588} = 430\,(\text{m}^2),$$

Wing span can be calculated using area of a wing and aspect ratio:

$$l = \sqrt{S_{wing} \cdot \lambda_w} = \sqrt{430 \cdot 7.16} = 55.48\,(\text{m}),$$

where λ_w=7.16.

Root chord of the wing is equal to:

$$C_{root} = \frac{2S_w\eta_w}{(1+\eta_w)\cdot l} = \frac{2\cdot 430 \cdot 3.55}{(1+3.55)\cdot 55.48} = 12\,(\text{m}),$$

where taper ratio of the wing η_w = 3.55.

Tip chord of the wing is:

$$C_{tip} = \frac{C_{root}}{\eta_w} = \frac{12}{3.55} = 3.380\,(\text{m}),$$

Spar 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 two spars was chosen to meet the requirements of strength and at the same time to make the structure comparatively light.

Relative coordination of the spar's position is equal:

- for a wing with two spars: x_{1spar}=0.2 C_i; x_{2spar}=0.6 C_i from the leading edge of current chord in the wing cross-section

$$X_{1root} = 0.2 \cdot 12 = 2.4;\ X_{1tip} = 0.2 \cdot 3.38 = 0.676,$$

$$X_{2root} = 0.6 \cdot 12 = 7.2;\ X_{2tip} = 0.6 \cdot 3.38 = 2.028,$$

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

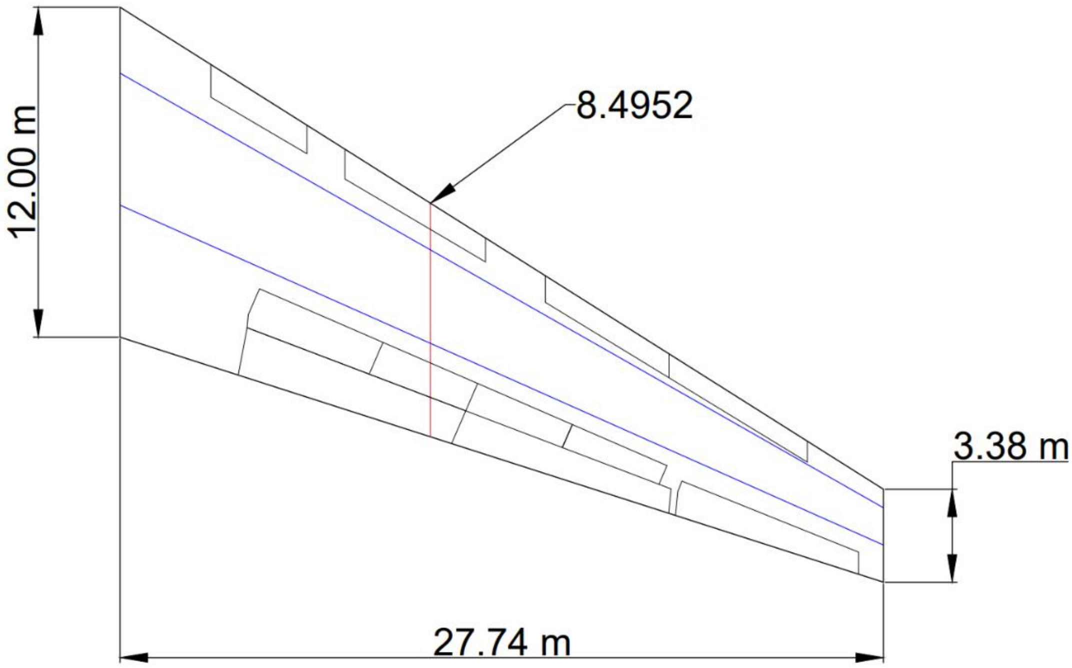

Figure 2.1. Determination of mean aerodynamic chord.

Mean aerodynamic chord is equal B_{mac}=8.4952 m.

Also MAC can be calculated using the following approximately formula for trapezoidal wing:

$$b_{MAC} = \frac{2}{3} \cdot \frac{C_{root}^2 + C_{root}C_{tip} + C_{tip}^2}{C_{root} + C_{tip}} = \frac{2}{3} \cdot \frac{12^2 + 12 \times 3.38 + 3.38^2}{12 + 3.38} = 8.49521 (\text{m}),$$

Aileron design

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 are crucial components of an aircraft's control system, located on the trailing edge of each wing. Ailerons primarily control the aircraft's roll motion around its longitudinal axis.

Aileron span:

$$l_{aileron} = (0.3 \ldots 0.4) \frac{l_{wing}}{2} = 6.43 \, (\text{m}),$$

Aileron chord:

$$C_{aileron} = (0.22 \ldots 0.26) C_i = 0.94 \, (\text{m}),$$

Aileron area:

$$S_{aileron} = (0.05 \ldots 0.08) \frac{S_{wing}}{2} = 13.76 \, (\text{m}^2),$$

The area of single ailerons is equal to 6.88 m^2.

For high lift device of a wing we will use double slotted flaps together with slats. Flaps and slats increase the lift produced by the wings, especially during takeoff and landing. By extending these devices, the wing's surface area increases, allowing it to generate more lift at lower speeds.

2.2. Fuselage layout

The fuselage is a critical component of an aircraft, providing structural support, occupant accommodation, aerodynamic efficiency, system integration, center of gravity management, crashworthiness, and maintenance accessibility. It serves as the backbone of the aircraft, integrating various systems and components to ensure safe, comfortable, and efficient flight operations.

Length of fuselage is equal to:

$$L_{fus} = FR \cdot D_{fuf} = 8.4 \cdot 6.86 = 57.6 \text{ (m)},$$

The width of cargo compartment is similar to the real prototype and is 5.5 m.

The length of cargo compartment is 31 m and 4.1 m height. These characteristics ensure easy and convenient loading of both oversized and non-oversized cargo. The cargo floor is designed to withstand the weight of an M-1 tank and to rapidly convert for rolling stock, pallets and airdrop. The actual floor is a series of longitudinal 7050 aluminum alloy planks extending the full length of the cargo compartment. The ramp not only ensures a pressure seal, it provides support for up to 40,000 pounds of payload in flight.

2.3. Tail unit geometrical parameters

The aircraft employs a rugged corrosion-resistant T-tail assembly consisting of a 41-degree swept-back vertical stabilizer with a variable-incidence horizontal stabilizer mounted on top. TU of the aircraft provides provide stability during flight and consist of 4 elevator surfaces and 2 rudder sections.

Area of HTU:

$$S_{HTU} = \left(0.18\ldots0.25\right)S = 78.5 \text{ (m}^2\text{)},$$

Area of VTU:

$$S_{VTU} = \left(0.12\ldots0.20\right)S = 63.63 \text{(m}^2\text{)},$$

Elevator area:

$$S_{el} = \left(0.3\ldots0.4\right)S_{HTU} = 28.61 \text{(m}^2\text{)},$$

Elevators consists of 4 section 7.1525 m^2 each

Rudder area:

$$S_{rudder} = (0.2\ldots0.22)S_{VTU} = 23.41\,(\text{m}^2),$$

Rudder consists of 2 section 11.705 m^2 each.

2.4. Landing gear design

The landing gear supports the weight of the aircraft during ground operations, takeoff, landing and absorbs the impact forces during landings. Chassis allows the aircraft to maneuver on the ground, taxiing to and from runways, parking areas, and maintenance facilities.

The plane has a nonsteerable six-wheel-per-side main landing gear that retracts into low-drag gear pods, and a steerable dual-wheel nose gear that retracts into the fuselage.

The main landing gear consists of dual struts on each side of the aircraft with three wheels on each strut in a lever suspension arrangement. Such LG scheme allows the aircraft to use short runways and to land and take off from ground runways.

The distance from the centre of gravity to the main LG:

$$B_m = (0.15\ldots0.20)b_{MAC} = 1.69\,(\text{m}),$$

Landing gear wheel base comes from the expression:

$$B = (0.3\ldots0.4)l_f = (6\ldots10)B_m = 20.65\,(\text{m}),$$

The distance from the centre of gravity to the nose LG:

$$B_n = B - B_m = 20.65 - 1.69 = 18.96\,(\text{m}),$$

Wheel track is:

$$T = (0.7\ldots1.2)B \le 12\text{m} = 7.62\,(\text{m}),$$

The load on the wheel is determined:

$$F_{main} = \frac{(B - B_m)m_0 \cdot 9.81}{B \cdot n \cdot z} = \frac{18.96 \cdot 299034 \cdot 9.81}{20.65 \cdot 12} = 224453\,(\text{N}),$$

$$F_{nose} = \frac{B_m \cdot m_0 \cdot 9.81 \cdot K_g}{B \cdot z} = \frac{1.69 \cdot 299034 \cdot 9.81 \times 1.5}{20.65 \cdot 2} = 180060 \text{ (N)},$$

224453 N = 50459 lbs and 180060 N = 40479 lbs

The right wheels ensure a smooth and safe landing, takeoff, and taxiing experience for the aircraft. They are a vital part of the landing gear system, playing a critical role in absorbing impact, enabling proper braking, and load spreading. Therefore, it is important to choose the proper wheels. Tires was chosen according to the maximum load and landing speed from the Goodyear catalogue.

For Main gears we take the type of tires from table 2.1:

Table 2.1

Aviation tires for main gears of designing aircraft

Size	Construction			Service Rating				Tread Design/ Trademark	Weight(Lbs)
	Ply Rating	TT or TL	Rated Speed (mph)	Rated load (Lbs)	Rated Inflation (Psi)	Max. Breaking Load (Lbs)	Max. Bottoming Load (Lbs)		
H49x19.0-22	32	TL	235	56	205	84900	152800	Flight Leader	248.5

Ending of the table 2.1

Inflated Dimensions (in)				Static Loaded Radius (in)	Aspect Ratio	Wheel (in)			
Outside DIA		Section Width				Width Between Flanges	Specified Rim Diameter	Flange Height	Min Ledge Width
Max	Min	Max	Min						
49	48	19	18,15	20.Tpa	0.713	12	22	1.7	3.95

For Nose gears we take the following type of tires from table 2.2:

Table 2.2

Aviation tires for nose gear of designing aircraft

Size	Construction			Service Rating				Tread Design/ Trademark	Weight(Lbs)
	Ply Rating	TT or TL	Rated Speed (mph)	Rated load (Lbs)	Rated Inflation (Psi)	Max. Breaking Load (Lbs)	Max. Bottoming Load (Lbs)		
H43.5x16.0-21	26	TL	225	40600	210	60900	109600	Flight Leader	169.8

Ending of the table 2.2

Inflated Dimensions (in)				Static Loaded Radius (in)	Aspect Ratio	Wheel (in)			
Outside DIA		Section Width				Width Between Flanges	Specified Rim Diameter	Flange Height	Min Ledge Width
Max	Min	Max	Min						
43.5	42.55	16	15.2	18.2	0.706	10.5	21	1.6	1.24

Figure 2.2. Nose and main landing gear tires.

2.5. Choice and description of power plant

The primary function of the aircraft engine is to generate thrust, which propels the aircraft forward. The engine serves as the power source for various aircraft systems and components, including electrical generators, hydraulic pumps, and air conditioning systems. It provides the necessary mechanical energy to drive these systems, ensuring their proper operation throughout all phases of flight.

The Pratt & Whitney PW2000, also known by the military designation F117 and initially referred to as the JT10D, is a series of high-bypass turbofan aircraft engines with a thrust range from 37,000 to 43,000 lbf (160 to 190 kN).

The PW2000 is a dual-spool, axial air flow, annular combustion, high bypass turbofan engine introduces groundbreaking advancements, boasting unmatched performance, eco-friendly attributes, exceptional reliability, and cost-effective maintenance. Like its PW4000 counterpart, the PW2000 is certified for 180-minute ETOPS flights, enabling operators to traverse vast distances across oceans and continents. Since its debut on the 757 in 1984, the engine has accrued over 26 million hours of service. Today's PW2000 engines incorporate various enhancements for increased durability, resulting in extended operational life and reduced maintenance expenses. With its robust thrust and remarkable fuel efficiency, the PW2000 facilitates superior payload capacity and excels in operating at high altitudes and in hot climates. Its main parameters are shown on Table 2.3 – Characteristics of P&W PW2000 engine.

Table 2.3

Characteristics of P&W PW2000 engine

Name	Type	Compressor	Weight	Thrust	Length	Bypass Ratio	Diameter	Overall pressure ratio
Pratt & Whitney PW2000	Turbofan	Axial, 1 stage fan with 36 blades, 4 stage LP, 12 stage HP	3,221 kg	170.81 – 194.54 kN	3,729 mm	6.0:1	1,994 mm	27.6-31.2:1

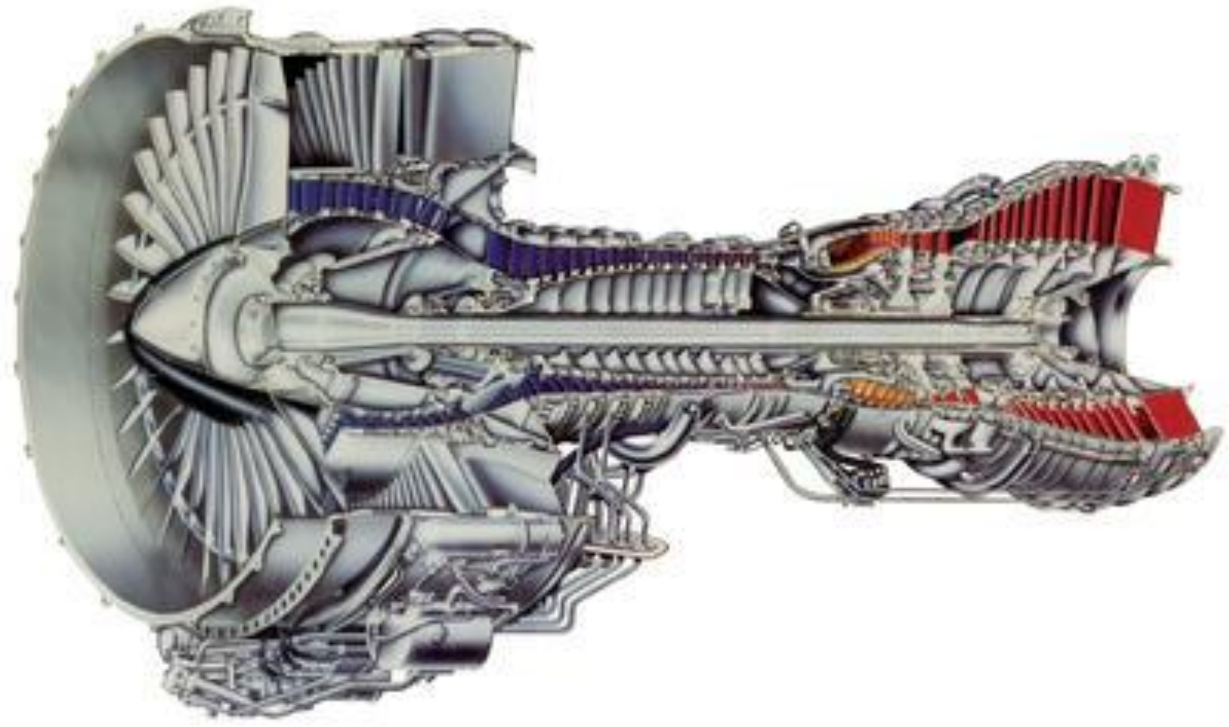

Figure 2.3. P&W PW2000 engine cutaway.

2.6. Determination of the aircraft center of gravity position

The center of gravity (CG) has a significant impact on an aircraft's stability and control. When the CG is excessively forward, resulting in a high static margin, the aircraft becomes nose-heavy, impeding its ability to pitch up during takeoff and climb. This configuration also leads to sluggishness along the longitudinal axis, making pitching challenging due to excessive stability. Conversely, if the CG is overly aft, with a low static margin, the aircraft becomes easier to maneuver in the pitch axis, exhibiting high agility but at the expense of decreased stability. Additionally, the CG influences lateral stability; if it deviates too far to one side, the aircraft may roll in that direction, posing a risk of loss of control and potential crashes during flight.

Numerous factors contribute to the center of gravity of an aircraft, including fuel load, passenger and cargo weights, equipment, systems, and modifications to the aircraft.

2.7. Determination of centering of the equipped wing

The mass of the equipped wing includes the weight of its structure, the weight of the equipment installed in the wing, and the weight of the fuel. The main landing gear and the front gear are included in the mass register of the equipped wing, regardless of their mounting location (whether on the wing or the fuselage). The mass register lists the names of the objects, their weights, and their center of gravity coordinates. These coordinates are referenced from the projection of the nose point of the mean aerodynamic chord (MAC) on the XOY plane. Positive coordinate values are used for the rear part of the aircraft.

Table 3.1

Trim sheet of equipped wing

№	object name	Mass		C.G coordinates X_i, m	Mass moment, $X_i * m_i$
		units	total mass m_i, kg		
1	wing (structure)	0.098	29427.936	3.568	104998.405
2	fuel system	0.008	2392.272	3.610	8637.202
3	Flight control system , 30%	0.001	287.073	5.097	1463.244
4	electrical equipment, 10%	0.001	358.841	0.850	304.842
5	anti-ice system , 40%	0.004	1291.827	0.850	1097.433
6	hydraulic systems , 70%	0.007	2093.238	5.097	10669.485
7	power plant position №1	0.050	14853.019	1.865	27703.851
8	power plant position №2	0.050	14853.019	-2.350	-34904.594
9	equipped wing without landing gear and fuel	0.219	65557.224	1.830	119969.868
10	fuel	0.253	75574.863	3.568	269651.111
11	total	0.472	141132.087	2.761	389620.978

2.8. Trim-sheet 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 3.2.

The CG coordinates of the FEF are determined by formulas:

$$X_f = \frac{\sum m_i' X_i'}{\sum m_i'},$$

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

$$m_f x_f + m_w \left(x_{MAC} + x_w' \right) = m_0 \left(x_{MAC} + C \right),$$

Origin of the coordinates is chosen in the projection of the nose of the fuselage on the horizontal axis. Determining the wing MAC leading edge position relative to fuselage, means X_{MAC} value by formula:

$$X_{MAC} = \frac{m_f x_f + m_w \cdot x_w' - m_0 C}{m_0 - m_w} = 20.35(\text{m}),$$

where: m_0 – aircraft takeoff mass, kg; m_f – mass of fully equipped fuselage, kg; x_f – coordinate on of fully equipped fuselage; m_w – mass of fully equipped wing, kg; x_w – coordination of fully equipped wing; C – distance from MAC leading edge to the C.G. point, determined by the designer. C = (0.23...0.32) B_{MAC} – high wing.

Table 3.2

Trim sheet of equipped fuselage

№	objects names	Mass		C.G coordinates X_i, m	mass moment
		units	total mass		
1	2	3	4	5	6
1	fuselage	0.092	27448.331	26.500	727380.768
2	horizontal tail	0.016	4641.008	52.500	243652.903
3	vertical tail	0.018	5280.940	49.300	260350.364
4	radar	0.004	1166.233	0.500	583.116
5	radio equipment	0.003	867.199	1.500	1300.798
6	instrument panel	0.007	2033.431	3.000	6100.294
7	aero navigation equipment	0.006	1764.301	1.500	2646.451
8	Flight control system 70%	0.002	669.836	18.000	12057.051
9	hydraulic system 30%	0.003	897.102	14.000	12559.428
10	electrical equipment 90%	0.011	3229.567	20.000	64591.344
11	not typical equipment	0.002	508.358	7.300	3711.012
12	lining and insulation	0.005	1435.363	4.000	5741.453
13	anti ice system, 20%	0.002	645.913	16.000	10334.615
14	airconditioning system, 40%	0.004	1291.827	15.000	19377.403
15	seats for accomp.person	0.000	59.807	3.500	209.324
16	cargo cabin equipment(upper and lower equipment)	0.045	13426.627	7.500	100699.700
17	Nose landing gear	0.004	1306.181	3.350	4375.705
18	Main landing gear	0.039	11755.625	24.000	282134.991

Ending of table 3.2

1	2	3	4	5	6
19	Operational items	0.006	1725.426	8.000	13803.409
20	equipped fuselage without payload	0.268	80153.073	22.103	1771610.127
21	Payload	0.260	77748.840	23.000	1788223.320
22	TOTAL	0.528	157901.913	22.545	3559833.447

2.9. Calculation of center of gravity positioning variants

The list of mass objects for center of gravity variant calculation given in Table 3.3 and Center of gravity calculation options given in table 3.4, completes on the base of both previous tables.

Table 3.3

Calculation of C.G. positioning variants

Name	Mass	Coordinate	Mass moment
object	m_i , *kg*	X_i, *m*	*kgm*
equipped wing (without fuel and landing gear)	65557.224	22.177	1453830.167
Nose landing gear (extended)	1306.181	3.350	4375.705
main landing gear (extended)	11755.625	24.000	282134.991
fuel reserve	11010.432	23.915	263309.014
fuel for flight	64564.431	23.915	1544026.325
equipped fuselage (without payload and landing gear)	67091.268	22.103	1482907.208
payload	77748.840	23.000	1788223.320
Nose landing gear (retrected)	1306.181	1.450	1893.962
main landing gear (retrected)	11755.625	24.000	282134.991

Table 3.4

Airplanes C.G. position variants

№	Object name	Mass, m_i kg	Mass moment m_iX_i	Center of mass X_m	Centering, %
1	take off mass (L.G. extended)	299034.000	6818806.731	22.803	28.914%
2	take off mass (L.G. retracted)	299034.000	6816324.988	22.794	28.816%
3	landing weight (LG extended)	234469.569	5274780.405	22.497	25.310%
4	ferry version (no payload, max fuel, LG retracted)	221285.160	5028101.668	22.722	27.966%
5	parking version (without payload, fuel, LG extended)	156720.729	3486557.085	22.247	22.371%

Conclusion to the project part

Based on the data of three prototypes, a new midrange cargo plane was created, which absorbed their best qualities.

Thus, the length of the new aircraft is 57.6 m with a payload of 80,000 kilograms, and a large cargo compartment allows for the transportation of a variety of luggage.

The geometric characteristics of the new wing were calculated. The area of the wing is 430 m.

The location of the control elements, systems and equipment of the aircraft in the wing and fuselage was also distributed.

The centering of the aircraft was calculated in such way to provide the best aircraft's stability and control properties.

A new landing gear was also chosen to meet all the requirements of the new aircraft. The choice fell on the Flight leader tires manufacturer, which is famous for its reliability, durability, as well as the ability to withstand high loads.

Time-tested P&W PW2000 engine will provide the necessary thrust and safety during flight.

3. ELECTRICAL HOIST FOR MIDRANGE CARGO AIRCRAFT

3.1. The application of electrical hoists

The history of hoisting dates back thousands of years, with early civilizations using simple machines like pulleys and ropes to lift heavy objects. The development of electrical hoists began in the late 19th century with the advent of electric motors. The invention of the electric motor enabled the development of the first electric hoists. These early hoists were primarily used in industrial settings for lifting heavy machinery and materials.

Today, the Telfer in its classic presentation is an electric hoist equipped with a carriage (trolley) for movement. Originating from Greek, "telfer" combines "far" and "carrying," succinctly capturing its primary purpose. Essentially, the telpher not only elevates loads vertically but also facilitates their horizontal displacement along designated tracks, typically I-beams.

By design, hoists are either rope (cable) or chain. In the case of electric hook hoists, commonly utilized in workshops, warehouses, and various other applications for transporting goods with a load capacity of 1-5 tons, rope hoists are used as cargo trolleys. Rope electric hoists have a greater load capacity compared to chain hoists, which is why they are used for transporting medium and heavy loads

Electric hoists find extensive application across multiple industries, including manufacturing, construction, warehouses, and production, facilitating the lifting of hefty loads. They serve either autonomously or as integral components within more intricate lifting systems, notably cranes such as bridge, gantry, cantilever, and jib cranes. Employing an electric hoist enables swift and secure elevation of even the most intricate, weighty, and cumbersome loads.

Hoists have also found their application in the aviation sector. Cargo aircrafts with overhead loading devices (telfers), in contrast to manual lifting mechanisms, provide a very high speed of work and can significantly increase its efficiency, reliability and personnel productivity. Telpher equipment is designed for loading without wheeled vehicles and other various cargoes.

Installing a hoist on an aircraft yields dependable, secure, and steadfast equipment that significantly simplifies human labor. The merits of such lifting mechanisms encompass:

- Compact dimensions and lightweight construction, facilitating effortless installation, disassembly, transportation, and utilization within confined spaces.

- Extensive operational lifespan, devoid of components necessitating frequent replacement or repair. With minimal and proper upkeep, such apparatus can endure for decades without malfunction.

- Broad versatility, with telefers available in diverse makes and models on the contemporary market, boasting varied technical specifications. This diversity enables straightforward selection of the most suitable options tailored to requisite load capacities for future tasks.

3.2. Installation of electrical hoist

The biggest structural difference and feature of electric hoists installed on an aircraft is that the voltage frequency used on the aircraft is 400 Hz, which is much higher than those used in everyday life - 60 Hz.

As the frequency of the voltage change was made slower, the size and weight of the transformers and generators increased and became more expensive.

As the frequency was made faster, more power was lost in the transmission lines, which also increased cost.

When aviation began using electricity, it was DC power. As AC became more prevalent in aircraft, the primary concern was the size and weight of transformers, motors and power supplies. The idea was proposed to use a higher frequency to make the components lighter, since the length of power transmission was small, the increased power loss would be negligent.

Telfer has a relatively small own weight, but is able to withstand serious loads. It works in the temperature range from −40 to +40 degrees Celsius and does not react to changes in air humidity. Due to such properties, the hoist is a reliable and high-quality equipment, economical in maintenance. That is why it was decided to install such a system in the designed aircraft.

The overhead equipment includes:

- 4 electric hoists installed on the right and left sides of the aircraft in the cargo compartment (2 each);
- 2 rails (right and left), installed on the ceiling of the cargo compartment;
- locking device for each hoist.

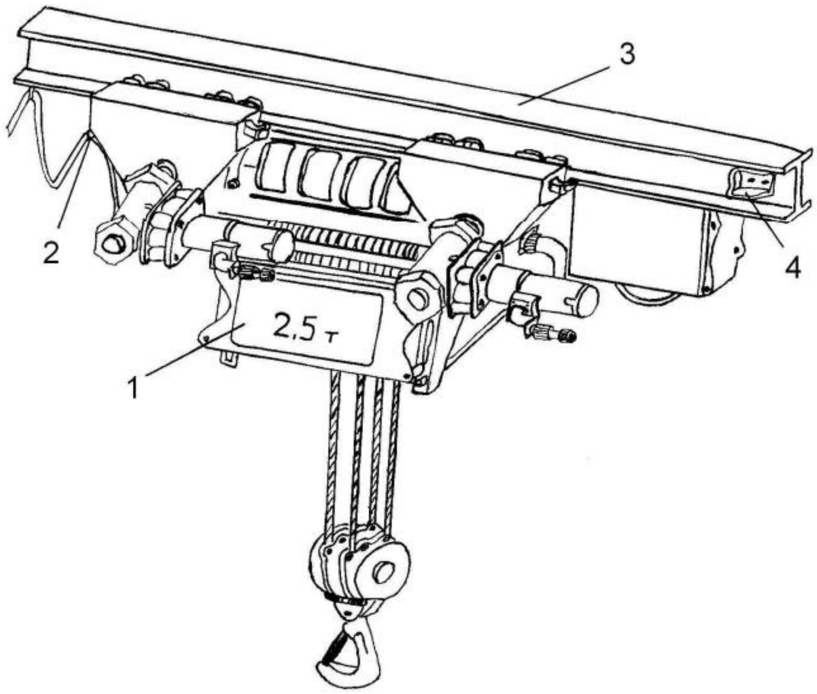

Figure 3.4. – Electrical hoist: 1 – Winch; 2 – carriage with a cable; 3 – I-beam; 4 – stop.

Loading of cargo weighing up to 2.5 tons is carried out by one hoist, weighing from 2.5 to 5 tons - by two, weighing from 5 to 10 tons - by four.

Electric hoists move along rails at a distance along all cargo bay of the aircraft. The height of the rails from the floor of the cargo compartment is 3750 mm, each rail consists of 6 sections.

The electric hoist consists of the following parts:

– electric winches LPG-1500A;

– 2 carriages for moving the electric hoist along the rail, installed on the rail;

– 2 electric mechanisms for telpher carriages MKT-1A. The mechanism is installed inside the aircraft and attached to the hoist carriage;

– electric hoist control panel PUT-1AM;

– moving block dynamometer.

Electric hoist carriages move along the rail using electric mechanisms MKT-1A (electric motor with gearbox). An LPG-1500 electric winch. The control of electric winches and carriages (lowering, lifting, forward, backward movements) is carried out using a portable control panel PUT-1AM, on which buttons with the inscriptions “LOADING AND UNLOADING” are installed, when pressed, the electric hoist moves forward (in the direction of flight) and backward, respectively. To raise and lower the load, a LOWER-LIFT control handle is installed on the side. Hoist characteristics are in table 4.1.

Table 4.1

Technical characteristics of the electric hoist

NAME	VALUE
Permissible load on the moving block, kg	3000
Lifting a load when two electric motors are running, m/min	1.5
Lifting a load when one electric motor is running, m/min	0.75
Lowering a load when two electric motors are running, m/min	2.25
Lowering a load when one electric motor is running, m/min	1.1
Speed of carriage movement by electric mechanism, m/min	10

The LPG-1500A series winch is designed for lifting and lowering loads weighing up to 3000 kg, its characteristics are in table 4.2.

Table 4.2

Technical characteristics of the electric winches LPG-1500A

Name	Value
DC supply voltage, V	27
DC supply voltage, frequency 400 Hz, V	200
Load capacity no more than, kg	3000
Speed of movement of the moving block when releasing/retracting the cable m/min, not less	2.25/1.5
Current consumed by the system, A, no more	14
Drum capacity (rope length), m	22
Rope diameter, mm	7.5
System weight, kg	100.6
Dimensions	320x390, 5x790

Included with the winch is an ADS-1000TV electric motor in the amount of 2 pieces. The power of such an electric motor can be calculated using the formula:

$$P = \frac{F \cdot V}{A \cdot \eta} = \frac{25000 \cdot 0.25}{1000 \cdot 0.875} = 7.35 \text{ (Kw)},$$

where: P – motor power in Kw; F – Maximum lifting load, N; V – retracting cable speed in m/sec; A – 1000; η – efficiency of electric motor.

The efficiency of an electric motor is measured as a percentage and averages 75 - 87.5%.

A rotating magnetic field is formed as a result of the interaction of the magnetic fields of the stator and rotor. The rotation frequency of the stator field n_1 depends on the frequency of the current and the number of pole pairs:

$$n_1 = 60\frac{f_1}{p} = \frac{60 \cdot 400}{4} = 6000\,(\text{HZ}),$$

where: F_1 – frequency of the current, HZ; p – number of pairs of magnetic poles of the stator winding.

Drum diameter of a winch

$$D_{drum} = (20...25) \cdot d_{wire} = (20...25) \cdot 7.5 = 182\,(\text{mm}),$$

Where d_{wire}=7.5 mm

Drum rotation frequency in 1/min

$$n_{drum} = \frac{60 \cdot V}{\pi \cdot D_{drum}} = \frac{60 \cdot 0.25}{3.14 \cdot 0.182} = 26.2\,(\text{HZ}),$$

3.2.1. Hook for electrical hoist

Hook is device attached to the hoisting mechanism that allows for the lifting and lowering of loads. This hook is typically equipped with a latch or safety mechanism to secure the load during operation.

Hooks come in various sizes and designs, depending on the capacity and application of the hoist. They are usually made of high-strength steel to withstand heavy loads and ensure safety during lifting operations. Hooks are an essential component of the hoisting system, providing a secure attachment point for the load being lifted. They are designed to distribute the weight of the load evenly and prevent it from slipping or falling during lifting and lowering operations. In addition to their primary function of lifting and lowering loads, hooks may also be equipped with additional features such as swivels or rotating mechanisms to facilitate easier maneuverability of the load.

Proper inspection and maintenance of hooks are critical to ensure their safe and efficient operation. Regular inspections should be conducted to check for signs of wear, deformation, or other damage that could compromise the integrity of the hook. Additionally, any safety mechanisms or latches should be inspected to ensure they are functioning correctly and securely.

Using the data obtained during the pre-diploma practice, the stresses arising in the cross section of the hook were calculated.

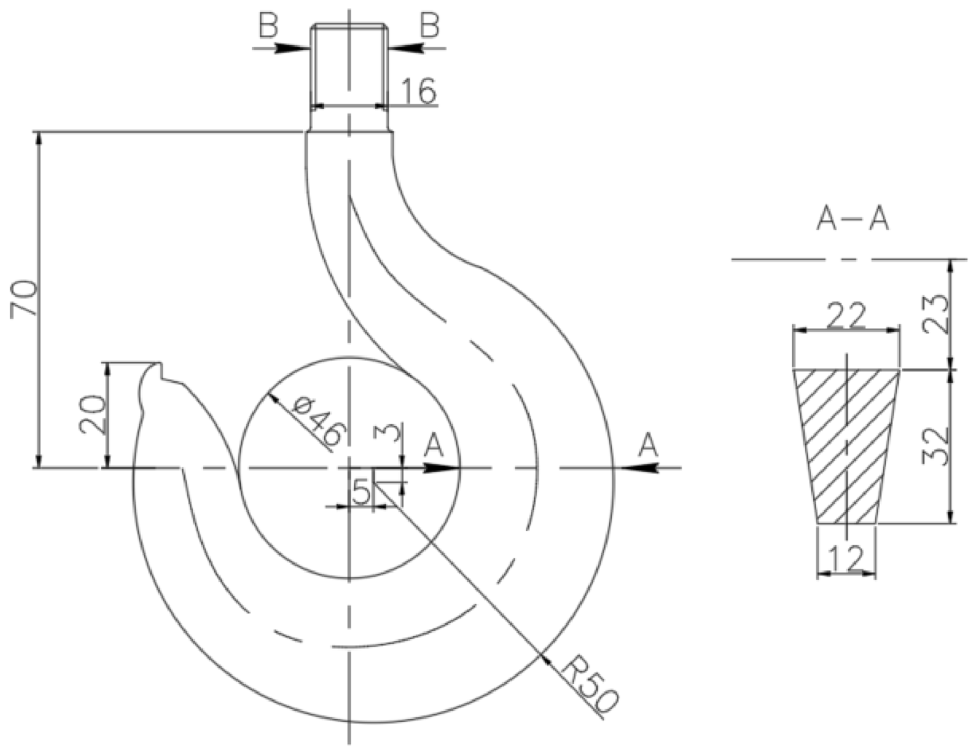

Figure 3.5. Hook with a cross section

Hook is made from steel 30ХГСА with tensile strength σ_B = 1080 MPa and able to operate load in P = 7500 kg.

Crossection A-A:

R_1=2.3 cm, R_2=5.5 cm, h=3.2 cm, a=1.2 cm, b=2.2 cm.

Area of cross section:

$$F = 0.5 \cdot (a+b) \cdot h = 0.5(1.2+2.2) \cdot 3.2 = 5.45 \text{ (cm}^2\text{)},$$

Distance of the center of gravity from the internal fibers:

$$c_1 = \frac{h}{3} \cdot \frac{2a+b}{a+b} = \frac{3.2}{3} \cdot \frac{2 \cdot 1.2 + 2.2}{1.2+2.2} = 1.44 \text{ (cm)},$$

Radius of curvature:

$$r = \frac{F}{\left(a + R_2 \cdot \frac{b-a}{h}\right) \cdot \ln \frac{R_2}{R_1} - (b-a)},$$

$$r = \frac{5.45}{\left(1.2 + 5.5 \cdot \frac{2.2-1.2}{3.2}\right) \cdot \ln \frac{5.5}{2.3} - (2.2-1.2)} = \frac{5.45}{2.92 \cdot 0.87 - 1} = 9.54 \text{ (cm)},$$

$$R_o = R_1 + c_1 = 2.3 + 1.44 = 3.74 \text{ (cm)},$$

$$z = R_o - r = 3.74 - 3.54 = 0.2 \text{ (cm)},$$

$$S = F \cdot z_o = 5.45 \cdot 0.2 = 1.09 \text{(cm}^3\text{)},$$

$$z_1 = c_1 - z_0 = 1.44 - 0.2 = 1.24 \text{ (cm)},$$

Tension in the cross section of the hook in internal fibers:

$$\sigma_1 = \frac{P}{F} + \frac{M \cdot z_1}{S \cdot R_1 \cdot K} = \frac{7500}{5.45} \cdot \frac{7500 \cdot 3.74 \cdot 1.24}{1.09 \cdot 2.3 \cdot 1.5} = 1380 + 9300 = 10680 \text{ (kg/cm}^2\text{)},$$

where: P – maximum operate load; F - cross-sectional area; M – bending moment in the section, determined relative to the z0 axis passing through the center of gravity of the cross section, $M = P \cdot R_0$; z_1 – distance to the fiber in question from the neutral z-axis; R_1 – radius of curvature of the fiber in question.

Safety factor:

$$\eta = \frac{\sigma_B}{\sigma_1} = \frac{11000}{10680} = 1.029,$$

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where: η - safety factor.

Crossection B-B is a circle:

Thread – 257AT

Thread body diameter:

$$d_{nom} = d - 1,2269S = 16 - 1.84 = 14(\text{mm}),$$

Break area:

$$F_{14} = \pi \cdot r^2 = 3,14 \cdot 0.7^2 = 1.589(\text{cm}^2),$$

Tensile stresses in the section:

$$\sigma_2 = \frac{P}{F} = \frac{7500}{1.539} = 4900(\text{kg/cm}^2),$$

Safety factor:

$$\eta = \frac{\sigma_B}{\sigma_2} = \frac{11000}{4900} = 2.2,$$

3.2.2. Cargo non-adjustable beam for electrical hoist

One of the greatest risks when lifting heavy objects is the potential for load damage. Using a single point of attachment, like a crane hook, concentrates the load's weight in a small area, which can deform or damage the object. Traverses, or cargo beams, allow the weight of bulky cargo to be evenly distributed over several lifting points, which reduces the load on individual parts of the aircraft structure and prevents damage. By distributing the load across a wider area, the beams prevent it from swinging or tilting, which could lead to instability and potential falls. This improves stability boosts safety and facilitates easier control of the load during lifting and transport. They can be integrated with hoists and other lifting mechanisms to provide a comprehensive cargo handling system. Some traverses have the ability to adjust the length and position of the lifting points, which allows them to be adapted for different types of cargo. The traverses are made of high-strength materials such as steel or aluminum to withstand heavy loads and ensure a long service life.

The use of traverses allows you to handle loads with non-standard shapes or sizes that cannot be lifted using standard methods. When transporting aircraft or space components, traverses ensure the safe lifting and handling of delicate and expensive goods. Traverses are widely used to transport heavy machinery, automobiles, construction machines and other oversized equipment that requires special handling.

Figure 3.6. – non-adjustable cargo beam

With the help of the ANSYS software, one such element was calculated for the stresses that occur during the load on the beam, as well as its deformation.

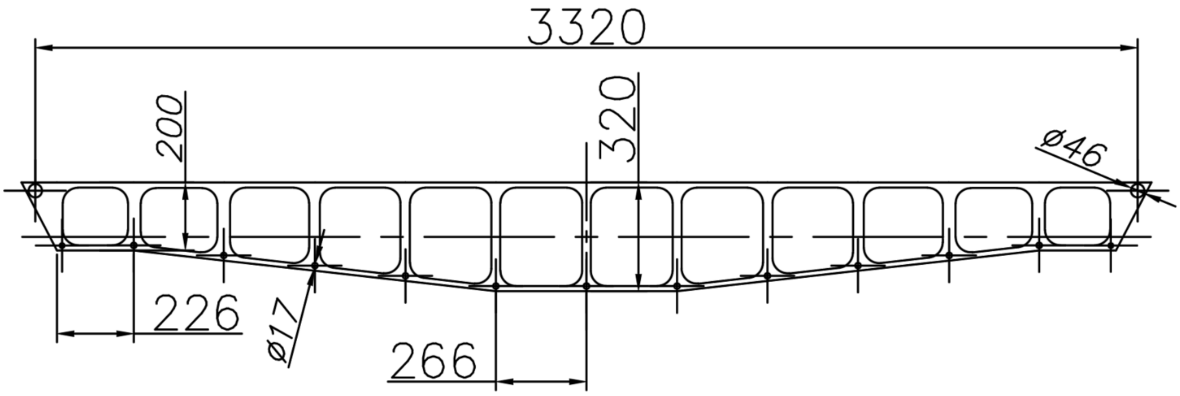

Figure 3.7. Geometry of cargo beam.

The hoist beam ensures the paired operation of two electric hoists when loading or unloading cargo and wheelless equipment from 2.5 to 5 tons. The telpher beam is a traverse of a welded structure, at both ends of which there are holes for hanging the beam on hooks. The beam has holes for securing the load and stencils are applied to the position of the load's centers of gravity.

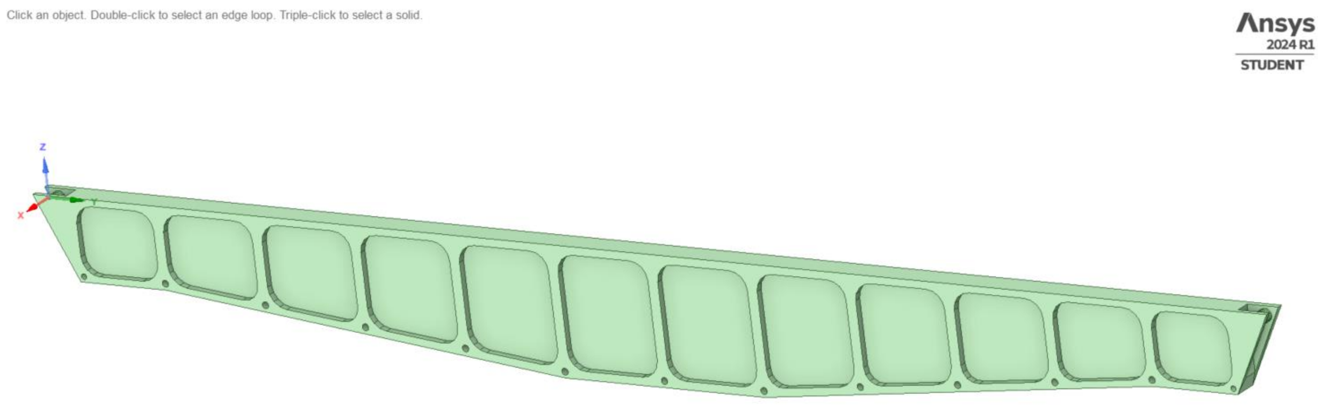

Figure 3.8. Geometry of cargo beam.

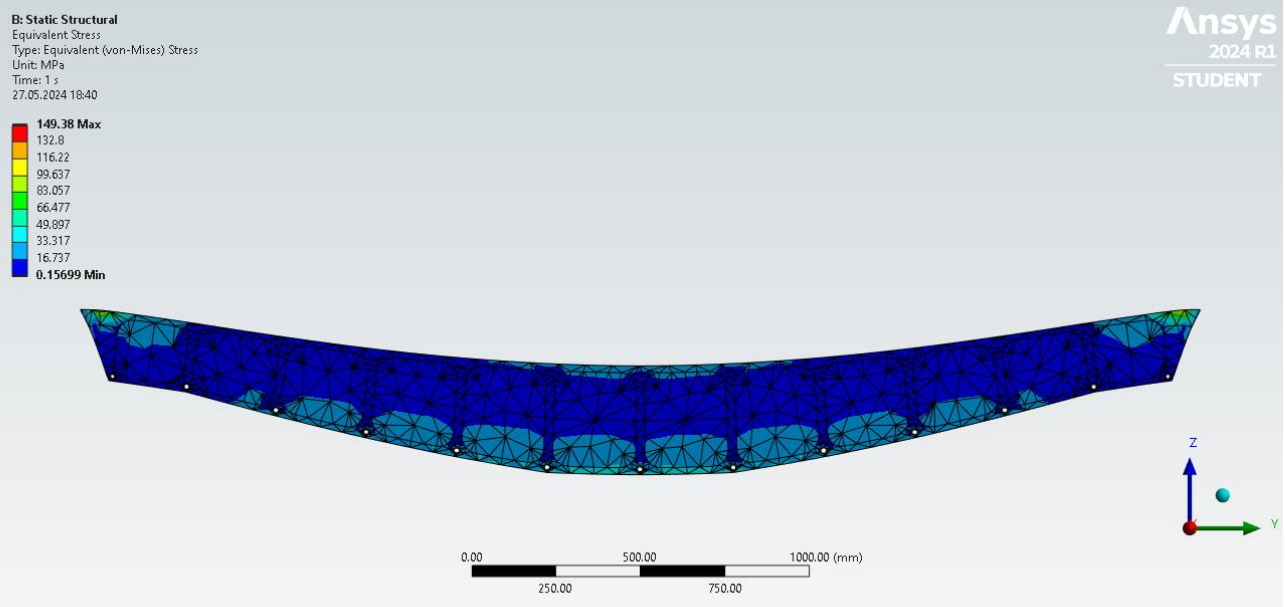

Figure 3.9. Stresses occuring during maximal loading on the beam.

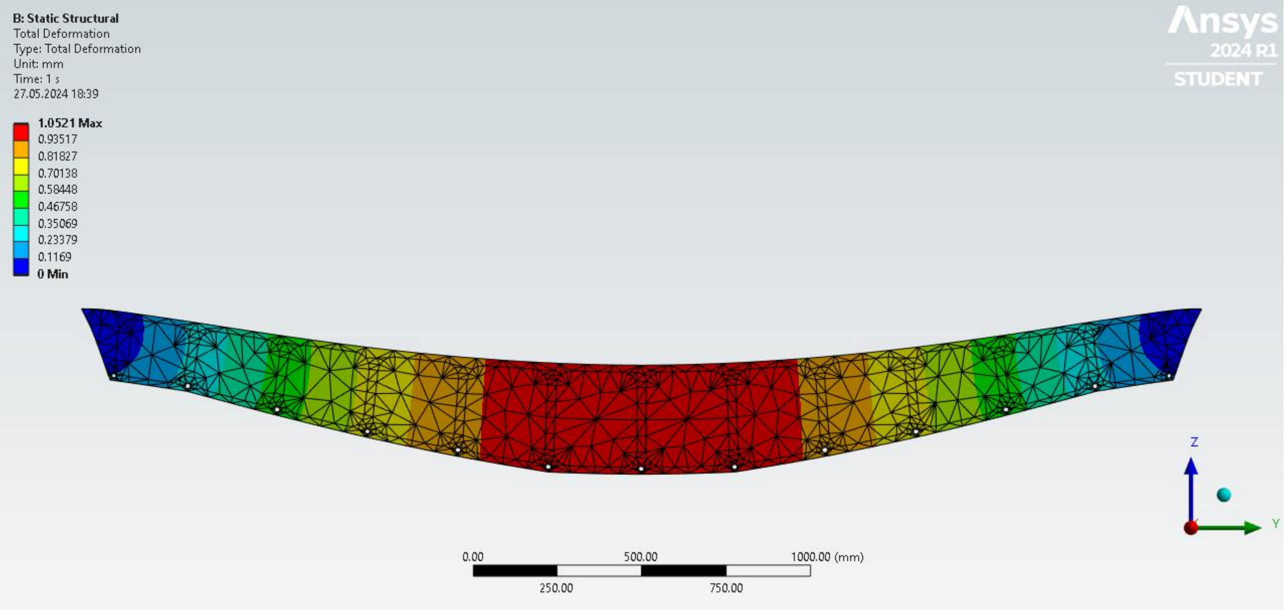

Figure 3.10. Deformation occuring during maximal loading on the beam.

Conclusion to the special part

Electric hoists are widely used in various industries, including aviation. In cargo aircraft, electric hoists play an important role and are used to raise, lower and move cargo onto the platform or floor of the aircraft. They allow quick and easy loading and unloading of cargo aircraft, saving time and money, equipped with various safety features to help prevent injury and cargo damage, easy to use, making them ideal for cargo operations. That is why it was chosen to equip the projected aircraft with it. 4 electric hoists with a carrying capacity of 2500 kg each were installed on board. The power of their motor was calculated, as well as the stresses arising in the cross-section of the lifting hook. Also, with the help of ANSYS software, the stress and deformation occurring in the non-adjustable cargo beam were calculated.

GENERAL CONCLUSION

As a result of this work, a preliminary design of a new medium-range cargo aircraft was created. Its main geometric parameters such as wing, fuselage, tail, landing gear and engine were calculated. The centering of the aircraft was calculated to provide the aircraft's stability and control.

Therefore, a new aircraft with a length of 57.6 m, a wingspan of 55.48 m and an area of 430 m^2 with a maximum take-off weight of 299034 kg was obtained. The carrying capacity is 80000 kg and maximum range of flight 4100 km.

The task of the special unit was to install an electric hoist in the cargo compartment. Its basic characteristics were determined and calculated. the hook and load beam were also calculated for stress.

The result of the work was a hoist in the amount of 4 pieces with a motor power of 7.35 kW and a load capacity of 2500 kg each. Such equipment will greatly facilitate the process and time of loading and unloading operations. The hook is safe and can withstand a load of 7500 kg, and the load beam will help in weight distribution.

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Appendix A

Performed by: Suliava Dmytro
Supervisor: Karuskevich Mykhailo

PRELIMINARY DESIGN OF THE AIRCRAFT
INITIAL DATA AND SELECTED PARAMETERS

Passenger Number	0.
Flight Crew Number	3.
Flight Attendant or Load Master Number	3.
Mass of Operational Items	1740 kg
Payload Mass	80000 kg
Cruising Speed	850. km/h
Cruising Mach Number	0.7966
Design Altitude	11.00 km
Flight Range with Maximum Payload	4100. km
Runway Length for the Base Aerodrome	2.2 km
Engine Number	4.
Thrust-to-weight Ratio in N/kg	3.3
Pressure Ratio	28.00
Assumed Bypass Ratio	6.30
Optimal Bypass Ratio	5.00
Fuel-to-weight Ratio	0.2500
Aspect Ratio	7.16
Taper Ratio	3.55
Mean Thickness Ratio	0.118
Wing Sweepback at Quarter Chord	29.0 deg
High-lift Device Coefficient	0.97
Relative Area of Wing Extensions	0.000

Wing Airfoil Type - Supercritical
Winglets - Installed
Spoilers - Installed

Fuselage Diameter	6.86 m
Fineness Ratio	8.4
Horizontal Tail Sweep Angle	33.0 deg
Vertical Tail Sweep Angle	38.0 deg

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point	0.39157
Induce Drag Coefficient	0.00911

ESTIMATION OF THE COEFFICIENT Dm = Mcritical - Mcruise

Cruising Mach Number	0.79660
Wave Drag Mach Number	0.80533
Calculated Parameter Dm	0.00873

Wing Loading in kPa (for Full Wing Area):

At Takeoff	4.588
At Middle of Cruising Flight	3.958
At the Beginning of Cruising Flight	4.410

Drag Coefficient of the Fuselage and Nacelles	0.00778
Drag Coefficient of the Wing and Tail Unit	0.00916
Drag Coefficient of the Airplane:	
At the Beginning of Cruising Flight	0.02803
At Middle of Cruising Flight	0.02699
Mean Lift Coefficient for the Ceiling Flight	0.39157
Mean Lift-to-drag Ratio	14.50656
Landing Lift Coefficient	1.506
Landing Lift Coefficient (at Stall Speed)	2.259
Takeoff Lift Coefficient (at Stall Speed)	1.882
Lift-off Lift Coefficient	1.374
Thrust-to-weight Ratio at the Beginning of Cruising Flight	0.643
Start Thrust-to-weight Ratio for Cruising Flight	2.732
Start Thrust-to-weight Ratio for Safe Takeoff	2.467
Design Thrust-to-weight Ratio	2.842
Ratio Dr = Rcruise / Rtake-off	1.108

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

Takeoff	34.7809
Cruising Flight	57.4515
Mean cruising for Given Range	59.3532

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.03682
Block Fuel	0.21591

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.09841
Horizontal Tail	0.01552
Vertical Tail	0.01766
Landing Gear	0.04368
Power Plant	0.09934
Fuselage	0.09179
Equipment and Flight Control	0.10571
Additional Equipment	0.00168
Operational Items	0.00582
Fuel	0.25273
Payload	0.26753

Airplane Takeoff Weight	299034. kgf
Takeoff Thrust Required of the Engine	212.44 kN

Air Conditioning and Anti-icing Equipment Weight Fraction	0.0108
Passenger Equipment Weight Fraction (or Cargo Cabin Equipment)	0.0002
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.0048
Furnishing Equipment Weight Fraction	0.0449
Flight Control Weight Fraction	0.0032
Hydraulic System Weight Fraction	0.0100

Electrical Equipment Weight Fraction	0.0120
Radar Weight Fraction	0.0039
Navigation Equipment Weight Fraction	0.0059
Radio Communication Equipment Weight Fraction	0.0029
Instrument Equipment Weight Fraction	0.0068
Fuel System Weight Fraction	0.0080

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)	0.0017

TAKE-OFF DISTANCE PARAMETERS

Airplane Lift-off Speed	263.03 km/h
Acceleration during Takeoff Run	2.18 m/s*s
Airplane Take-off Run Distance	1220. m
Airborne Take-off Distance	472. m
Take-off Distance	1692. m

CONTINUED TAKE-OFF DISTANCE PARAMETERS

Decision Speed	236.73 km/h
Mean Acceleration for Continued Take-off on Wet Runway	0.98 m/s*s
Take-off Run Distance for Continued Take-off on Wet Runway	1481.96 m
Continued Take-off Distance	1954.20 m
Runway Length Required for Rejected Take-off	2025.43 m

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight	245423. kg
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight	22.7 min
Descent Distance	53.56 km
Approach Speed	244.75 km/h
Mean Vertical Speed	1.98 m/s
Airborne Landing Distance	515. m
Landing Speed	229.75 km/h
Landing run distance	723. m
Landing Distance	1238. m
Runway Length Required for Regular Aerodrome	2068. m
Runway Length Required for Alternate Aerodrome	1758. m

ECONOMICAL EFFICIENCY

The equipped aircraft mass to payload mass ratio	1.7864
The mass of empty equipped aircraft per 1 passenger	0.00 kg/p
Relative performance with full load	442.22 km/h
Aircraft performance with maximum payload	64018.4 kg*km/h
Average time fuel consumption	12601.424 kg/h
Average distance fuel consumption	15.75 kg/km
Average fuel consumption for ton-kilometer	196.841 g/t*km
Average fuel consumption for passenger-kilometer	0.0000 g/p*km
Approximate evaluation of relative expenses for ton-km	0.2535 $/t*km

Appendix B

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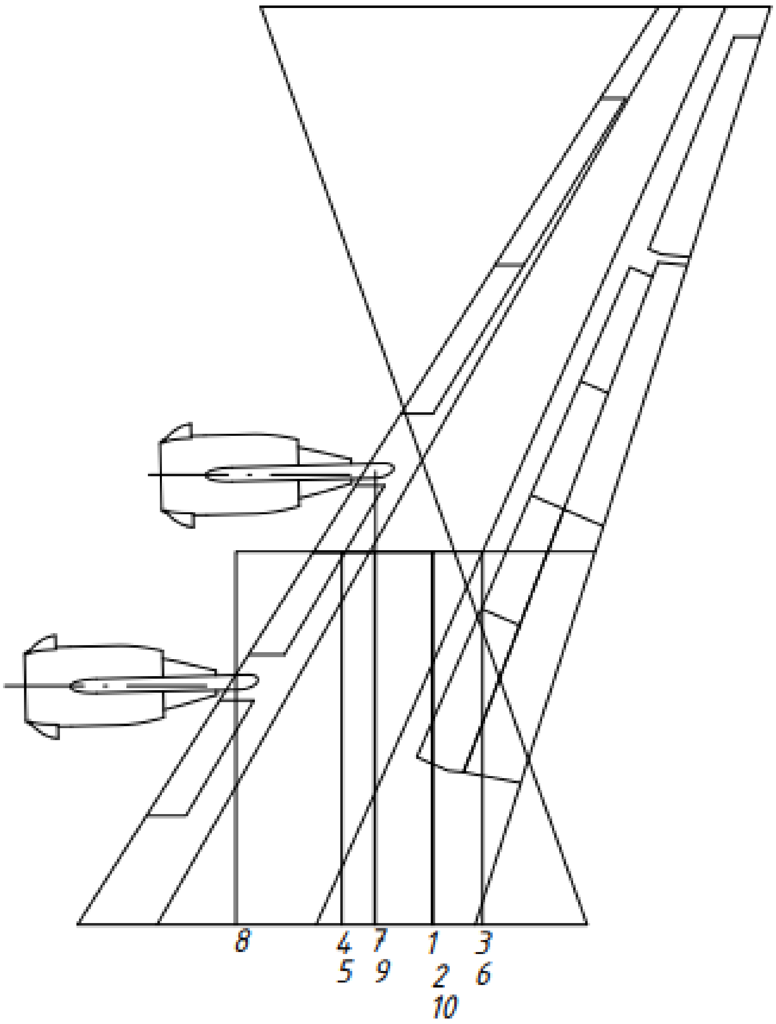


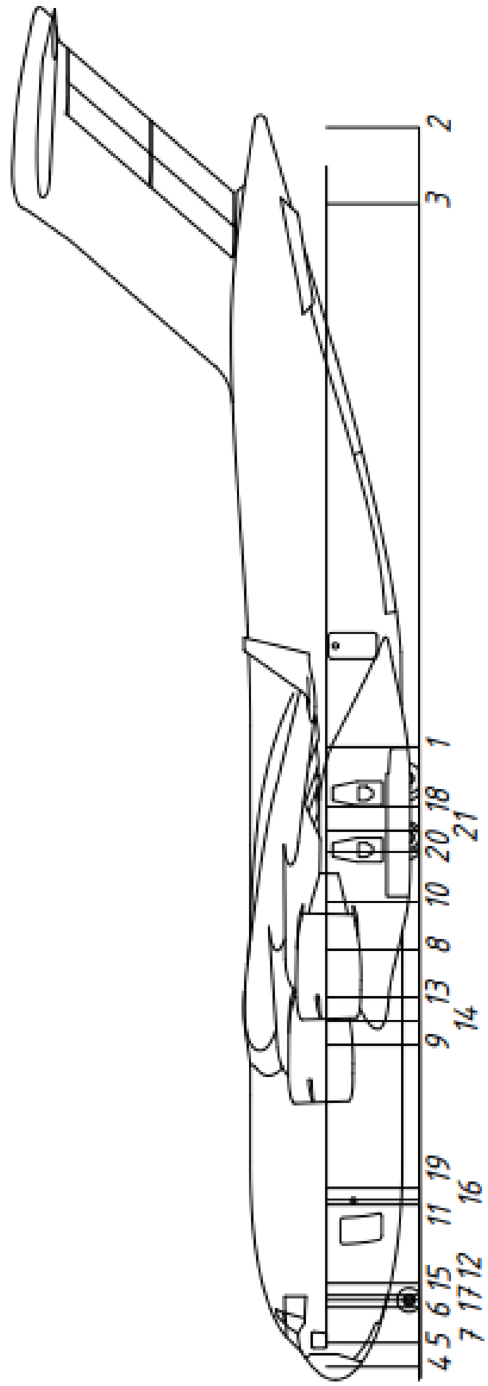
Ch	Sheet	Document #	Sign.	Date
Performed		Suliava D.Y		
Cheked		Karuskevych M.V		
Tech. control				
Reviewd		Krasnopolskiy V.S		
Approved		Yutskevych S.S		

NAU 24 06S 00 00 00 14GV			
Mean aerodynamic chord of a wing Trim sheet of a wing	Letter	Weight	Scale
	S		1:100
	Sheet 3	Sheets 3	
Apendix B	404 ASF 134		

N	object name	C.G coordinates Xi, m
1	wing (structure)	3.568
2	fuel system	3.610
3	Flight control system , 30%	5.097
4	electrical equipment, 10%	0.850
5	anti-ice system , 40%	0.850
6	hydraulic systems , 70%	5.097
7	power plant	1.865
8	power plant	-2.350
9	equipped wing without landing gear and fuel	1.830
10	fuel	3.568

Appendix C

NAU 24 06S 00 00 00 14 GV



					NAU 24 06S 00 00 00 14GV		
Ch	Sheet	Document #	Sign	Date			
Performed		Suliava D.Y			Trim sheet of a fuselage	Letter: S	Weight:	Scale: 1:100
Cheked		Karuskevych M.V				Sheet 3	Sheets 3
Tech. control							
Reviewd		Krasnopolskiy V.S			Apendix B	404 ASF 134	
Approved		Yutskevych S.S					

N	objects names	C.G coordinates Xi, m
1	fuselage	26.5
2	horizontal tail	52.5
3	vertical tail	49.3
4	radar	0.5
5	radio equipment	1.5
6	instrument panel	3
7	aero navigation equipment	1.5
8	Flight control system 70%	18
9	hydraulic system 30%	14
10	electrical equipment 90%	20
11	not typical equipment	7.3
12	lining and insulation	4
13	anti ice system, 20%	16
14	airconditioning system, 40%	15
15	seats for accomp.person	3.5
16	cargo cabin equipment(upper and lower equipment)	7.5
17	Nose landing gear	3.35
18	Main landing gear	24
19	Operational items	8
20	equipped fuselage without payload	22.102
21	Payload	23