МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
КАФЕДРА КОНСТРУКЦІЇ ЛІТАЛЬНИХ АПАРАТІВ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри, д.т.н., проф.
___________ Сергій ІГНАТОВИЧ
«____» ___________ _ 2021 р.

ДИПЛОМНА РОБОТА
ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ «МАГІСТР»
ЗІ СПЕЦІАЛЬНОСТІ:
«АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА»

Тема: «Перевезення негабаритних вантажів ближньомагістральними літаками»

Виконавець: __________ **Максим ЛУТОВІНОВ**

Керівник: к.т.н., доц. __________ **Тетяна МАСЛАК**

Консультанти з окремих розділів пояснювальної записки:
охорона праці:
к.біол.н., доц. __________ **Вікторія КОВАЛЕНКО**

охорона навколишнього середовища:
д.т.н., проф. __________ **Тамара ДУДАР**

Нормоконтролер: к.т.н, доц. __________ **Сергій ХИЖНЯК**

Київ 2021

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
«___» _______________ 2021

MASTER DEGREE THESIS
ON SPECIALITY
"AVIATION AND AEROSPACE TECHNOLOGIES "

Topic: "Transportation of oversized cargo by short range aircraft"

Fulfilled by: ___________ **Maksym LUTOVINOV**

Supervisor:
PhD, associate professor ____________ **Tetiana MASLAK**

Labor protection advisor:
PhD, associate professor ____________ **Victoria KOVALENKO**

Environmental protection adviser:
Dr. of Sc., professor ____________ **Tamara DUDAR**

Standards inspector
PhD, associate professor ____________ **Sergiy KHIZNYAK**

Kyiv 2021

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

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

ЗАТВЕРДЖУЮ
Завідувач кафедри, д.т.н, проф.
__________ Сергій ІГНАТОВИЧ
«_____» _____________ 2021 р.

ЗАВДАННЯ

на виконання дипломної роботи студента

ЛУТОВІНОВА МАКСИМА РУСЛАНОВИЧА

1. Тема роботи: «Перевезення негабаритних вантажів ближньомагістральними літаками», затверджена наказом ректора від 8 жовтня 2021 року № 2173/ст.

2. Термін виконання роботи: з 11 жовтня 2021 р. по 31 грудня 2021 р.

3. Вихідні дані до роботи: маса комерційного навантаження 16000 кг, дальність польоту з максимальним комерційним навантаженням 1300 км, крейсерська швидкість польоту 800 км/год, висота польоту 11 км, габаритні розміри вантажної кабіни.

4. Зміст пояснювальної записки: аналіз вантажів для перевезення їх у вантажній кабіні літака, аналіз ефективних методів завантаження та перевезення негабаритного вантажу ближньомагістральними літаками, проектування механізму для завантаження негабаритного вантажу в кабіну літака.

5. Перелік обов’язкового графічного (ілюстративного) матеріалу: креслення загального виду вантажного літака, складальне креслення механізму для завантаження негабаритного вантажу.

6. Календарний план-графік:

№	Завдання	Термін виконання	Відмітка про виконання
1	Огляд літератури за проблематикою роботи. Аналіз варіантів завантаження ближньомагістральних літаків.	11.10.2021–13.10.2021	
2	Проведення досліджень та оцінка габаритів вантажу для заванантаження в літак.	14.10.2021–20.10.2021	
3	Дослідження проблеми негабаритних вантажів при перевезенні літаками.	21.10.2021–24.10.2021	
4	Розробка механізму для завантаження негабаритних вантажів.	25.10.2021–15.11.2021	
5	Виконання частин, присвячених охороні навколишнього середовища та охорони праці.	16.11.2021–21.11.2021	
6	Підготовка ілюстративного матеріалу, написання пояснювальної записки.	22.11.2021–29.11.2021	
7	Перевірка, редагування та виправлення пояснювальної записки.	30.11.2021–31.12.2021	

7. Консультанти з окремих розділів:

Розділ	Консультант	Дата, підпис	
		Завдання видав	Завдання прийняв
Охорона праці	к.біол.н., доцент Вікторія КОВАЛЕНКО		
Охорона навколишнього середовища	д.т.н, професор Тамара ДУДАР		

8. Дата видачі завдання: 8 жовтня 2021 року

Керівник дипломної роботи ____________ Тетяна МАСЛАК

Завдання прийняв до виконання ____________ Максим ЛУТОВІНОВ

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty
Department of Aircraft Design
Educational Degree «Master»
Specialty 134 «Aviation and Aerospace Technologies»
Educational Professional Program «Aircraft Equipment»

APPROVED BY
Head of Department,
Dr. Sc., professor
________ Sergiy IGNATOVYCH
«___» ________________ 2021

TASK

for the master degree thesis

Maksym LUTOVINOV

1. Topic: «Transportation of oversized cargo by short range aircraft», approved by the Rector's order № 2173/ст from 8 October 2021.
2. Period of work: since 11 October 2021 till 31 December 2021.
3. Initial data: payload 16 tons, flight range with maximum capacity 1300 km, cruise speed 800 km/h, flight altitude 11 km, cargo cabin dimensions.
4. Content: analyze of cargo transportation in the aircraft cargo cabin, analyze of effective method of loading and transportation of oversized cargo by short-range aircraft, conceptual design of mechanism for loading oversized cargo into the cargo cabin of the aircraft.
5. Required material: drawings of the general view of the cargo aircraft, design of the mechanism for loading of oversized cargo.

6. Thesis schedule:

№	Task	Time limits	Done
1	Cargo loading planning analysis for short range aircraft.	11.10.2021–13.10.2021	
2	Carrying out of researches for estimated cargo.	14.10.2021–20.10.2021	
3	Research of an oversized cargo transportation problem in aviation.	21.10.2021–24.10.2021	
4	Development of a mechanism for loading of oversized cargo.	25.10.2021–15.11.2021	
5	Execution of the parts, devoted to environmental and labor protection.	16.11.2021–21.11.2021	
6	Preparation of illustrative material, writing the report.	22.11.2021–29.11.2021	
7	Explanatory note checking, editing and correction.	30.11.2021–31.12.2021	

7. Special chapter advisers:

Chapter	Adviser	Date, signature	
		Task issued	Task received
Labor protection	PhD, associate professor Victoria KOVALENKO		
Environmental protection	Dr. of Sc., professor Tamara DUDAR		

8. Date of issue of the task: 8 October 2021 year

Supervisor: ____________ Tetiana MASLAK

Student: ____________ Maksym LUTOVINOV

РЕФЕРАТ

Пояснювальна записка дипломної роботи магістра «Перевезення негабаритних вантажів ближньомагістральними літаками»:

79 с., 34 рис., 15 табл., 41 джерел

Дана дипломна робота присвячена розробці аванпроекту вантажного літака для ближньомагістральних авіаліній з можливістю транспортування негабаритних вантажів, що відповідає міжнародним стандартам польотів, нормам безпеки, економічності та надійності, а також проектування механізму для завантаження негабаритного вантажу в кабіну літака.

Практичне значення результату дипломної роботи магістра полягає в підвищенні надійності та ефективності вантажних повітряних перевезень, збільшення логістичної варіативності перевезення негабаритних вантажів.

Матеріали дипломної роботи магістра можуть бути використані в навчальному процесі та в практичній діяльності конструкторів спеціалізованих проєктних установ.

Дипломна робота, аванпроєкт літака, компонування, центрування, механізм завантаження

ABSTRACT

Master degree thesis "Transportation of oversized cargo by short-range aircraft"

79 pages, 34 figures, 15 tables, 41 references

This master thesis is dedicated to preliminary design of short-range airplane for transportation of oversized load and estimation its flight performances as well as design of loading device for it.

Practical value of the work is improving the efficiency of load transportation by air and logistic variability of the transportation of oversized loads.

The materials of the master's diploma can be used in the aviation industry and in the educational process of aviation specialties.

Master thesis, preliminary design, cabin layout, center of gravity calculation, loading device

CONTENTS

INTRODUCTION

Air cargo transportation is the most optimal solution for the delivery of goods, taking into account the short transit time over long distances.

Transport cargo aircraft are specially designed for the transportation of different types of goods, most often for the needs of military transport aviation. Nowadays, the transport cargo airplanes are widely used in commercial cargo transportation system due to huge demand for air logistic and some design configurations. Increased cross-section of the airplane fuselage provides high cargo capacity. Special design of the landing gear give opportunity to use the cargo airplane in the wide range of the airfields. Cargo doors in the tail and nose of the aircraft provides maximum size of cargo that can be loaded on airplane and convenience of the cargo operation. While achieving the best technical characteristics for cargo transportation, such aircraft are the most expensive to design and operate.

The main advantage of air transportation is a guick delivery, but it is the most expensive way for cargo transportation. Some cargo is unique and reguires only air carriage, first of all, the most expensive goods and goods that require urgent delivery. These include perishable goods, valuable goods and high-value goods, including fashionable clothing, electronics, pharmaceuticals, industrial equipment, and the most expensive components, for example, for the aerospace industry. In some market segments, air delivery is the main method of transporting products. Thus, more than 80% of the total volume of cut flowers, about 70% of semiconductor microcircuits and more than 60% of expensive electronic products are transported by air.

Along with regular air transportation, in recent years, the segment of non-standard and unique large dimensional and heavy cargo transportation by air has been growing at a fairly rapid pace. That is why the design of the specific equipment for cargo loading/unloading is one of the actual demand in the air carriage system.

The aim of master degree thesis is the conceptual design of the load hoist with traverse for the cargo transportation on aircraft board, which is designed to deliver cargo without disassembly. Even more, the implementation of this equipment will significantly reduce the costs and terms of cargo loading and unloading in the airport.

PART 1. TRENDS IN THE AIR CARGO INDUSTRY. STATEMENT OF THE CARGO LOADING PROBLEM

1.1 Air carriage as a branch of goods transportation

Air carriage is an important business for an international air transport industry. For any company, which provides cargo-handling service, is essential to manage this process qualitatively. The most controlled branches for air cargo business are competent cargo staff, information and tracking system, loading procedure by special equipment, air cargo load planning, airport infrustructure with enough capacity.

Air carriage (cargo handling) process is very complex for a number of reasons. First of all this process has two subparts – arrival or receipt and departure or dispatch of cargo, which run simultaneously; also at the same time physical and documentary handling activates, all together with passengers and baggage handling in the airport.

Air cargo handling depends on the cargo load planing that describes how to load Unit Load Device (ULD) or oversized cargo into airplanes. Usually this process is performing near two hours before the flight by the operators of loading process according the requirements for cargo distribution stated in the trim sheet. The location and weight of each ULD has an important role on airplane center of gravity position and aircraft balance in level flight, if the cargo will be not correctly loaded it may not fly. Once the aircraft is loaded, the report form as “Certificate” is provided for the crew, that the cargo has been loaded in accordance with trim sheet requirements. In the certificate, the next items must be checked: airline/operator, details of flight like flight number, routing and date, airraft type and registration, distribution of loads, fit positions, weight allocation does not exceed the limits, other entries.

Nowadays air cargo load planning is usually manual task that is performing by load planners in the automated weight and balance system. This system provides solving of full air cargo load planning problem, however in practice there is also exist a lot of paper routine during cargo packing. On the one hand, this leads to high labor costs but often also to suboptimal results, as there is a constant pressure of time and the problem complexity can be quite high. In the competitive market of cargo delilvery, including of automated support system in load planning process can give a huge profit for cargo aircraft customers. This will increase productivity of their cargo load planning personal and provide high quality solutions for each flight.

To improve the cargo loading process the automated system is used. Some benefits could be obtained: quick and easy process of loading; more accurate result – the usage of formulas, decreases the delays and human errors; high efficientcy – decrease of fuel consumption due to less time; approved by different national Civil Aviation Authorities; the system is easy in learing that reduces training; support all modern freighter airplanes.

1.2 Cargo types shipped by air

The two main types of cargo that is transported with the help of cago airplanes are general cargo and special. Special cargo is a cargo that includes different types of cargo like heavy weight cargo or over-dimensional cargo, some dangerous and hazardous things, some cargo needs special temperature controlling environment. Another type of the special cargo may be some tissue samples of human, human organs, and some remains, and other valuable items.

If we are talking about general cargo is a cargo that is also delivered by the aircraft and this type of cargo may include the following cargo: machinery and hardware, electronics, retail and consumer goods. Also general types of cargo care clothing, textiles, toys and others. Cargo may be transported by different types of airplanes, including cargo, passenger, or combi [1].

A huge planning problem in air cargo delivery industry is how corretly load and locate the cargo in the airplane cargo cabin. This action will provide profitable and safe flight. Take into account that this “planning puzzle” must be solved for each airplane and for each flight. Today the process of planning is mostly completed manually, sometimes this action can be too long and with uncertain quality.

There are different types of goods, which are transported by cargo airplanes. The cargo may be something as small as a mobile phone, or as large as an part of airplane or for example airplane engine, or as long as mast of the sailing vessel.

Delivery by the air of cargo is safe and fastet way of transport any kind of cargo. There are some additional advantages of the air cargo delivery:

1) Sending of your cargo anywhere.

2) Low risk that the cargo will be damaged.

3) You can follow the status of your cargo.

4) Reliable arrival and departure time.

However, despite a lot of advantages of the air cargo delivery, such type of transportation is too expensive. Usually the prices of the delivery is in 10 to 50 times much more than land transport.

Therefore, there are some categories of the cargo that can be delivered in the neareas time, or as fast as possible, these are:

1) Urgent cargo: this type of cargo must be delivered in short time. For example it can be living animals, spare parts, emergency help.

2) Perishable: this type of cargo can degrade when it is not properly handled. For example, cargo that must be delivered cooled compartment. Also, this type of cargo must be in controlled environment and arrive as fast as possible. For example: medicines, flowers, or some food.

3) Valuable: This type of cargo is valuable and must be transported with security. It can be money, some art, etc.

4) Dangerous: Such type of cargo can harm an environment without some correct handle conditions. This cargo must be handled with care and the crew nust be trained in the case of accidents. Also, some additional equipment should be installed in aircraft, for example additional fireextinguishing system. For example such type of cargo is radioactive agents, some chemicals, etc.

1.3 Types of Unit Load Devices

While some cargo may be too small, a great portion of cargo that is carried by combined or freight only deliver is at least as large as wooden pallet. Most cargo is box-shaped, but irregular barrels, barrels, or simply bags are common. Often, several boxes are already stacked by the shipper on a wooden pallet and the airline should not separate them.

The packaging is often made of cardboard, wood or expanded polystyrene and can be wrapped in plastic wrap or protected with reinforced metal edges. The most important part of the cargo transportation is loading and unloading cargo from the airplane.

To speed up the process of the ground handling, the usually cargo is assembled into special cargo containers or pallets. They are called unit load devices (ULD). Figure 1.1 shows typical pallet and container.

Figure 1.1 - Types of ULD

The ULDs and cargo that is packed in them are loaded into aircraft cargo cabin. The ULDs are placed on special designated cargo positions and they are locked to the floor by special latches.

Since the airplane fuselage has something like circular cross section, the are ULDs, especially containers that have different shapes to effective use in the airplane's interior cargo cabin space. There are several frequently used ULD types shown in figure 1.2.

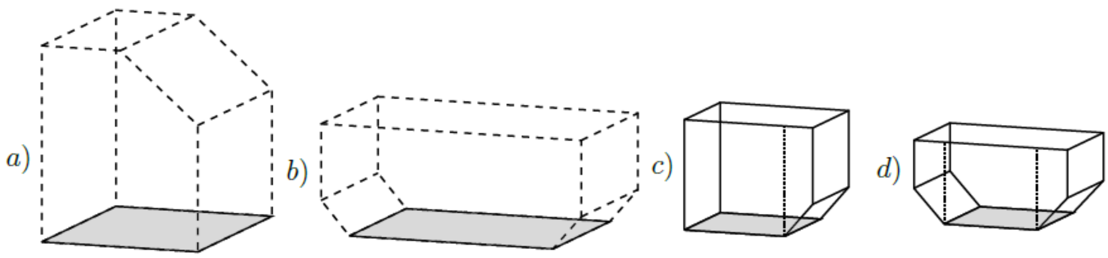


Figure 1.2 - Examples of ULDs

Allowed contour of filled pallet is shown with dashed lines. The solid line shows the walls of containers and floor sheets. There are the following types of ULDs:

a) main deck pallet (PMC) that is used in cargo aircraft .

b) lower deck pallet (PMC) that is used in wide-body passenger and cargo airplanes.

c) half-size lower deck container (AKE) that is used in wide-body passenger and cargo airplanes.

d) lower deck container (AKH) that is used in the narrow body passenger airplanes.

Containers have a contour and side walls that usually do no require some straps or net. So, as as understandant, containers can only be located in positions where containers contour fits in and the less handling effort for securing of ULD content is required. Containers are preferred for delivery of small shipments or small baggage.

Containers are typically lightweight structures that consist of aluminum profiles, a relatively thick (2.5mm-4 mm) aluminum base sheet, aluminum or composite side and roof panels, and a fabric or metal door. They must be as light as possible, they can be subjected to extremely hard handling conditions. Rapid growth in air travel, especially air cargo, over the past 10 years has resulted in some ULDs being processed in non-standard facilities using inappropriate processing techniques. Any resulting damage is not only a cost to aircraft operators, but can also create conditions that influence on the airplane safety.

As for pallets, they are usually preferred for large deliveres, it is easier to pack cargo than containers, because the contour of the pallets may be freely choosen. Also customer may pack pallets with cargo that is overhang and that can fill the full width of the aircraft's cabin. Usually, the pallets are make from wooden.

However, take into account that each pallet has to be covered with net and straps. When the pallet is packed, the extra handling effort is required to load it on airplane.

1.4 Loading of ULD on board

Final stage of loading process is to load packed ULDs into the airplane cargo cabin. Sometimes this process takes a much effort. Usually the pallets and containers are loaded into cargo compartments. In case the airplane does not have a special caego ramp, there are special designed vechicles that move the cargo upward. Than with the help of the rollers and latches with what the cargo floor is equipped, cargo latches to the airplane floor. Example of cargo loading is shown in the Figure 1.3.

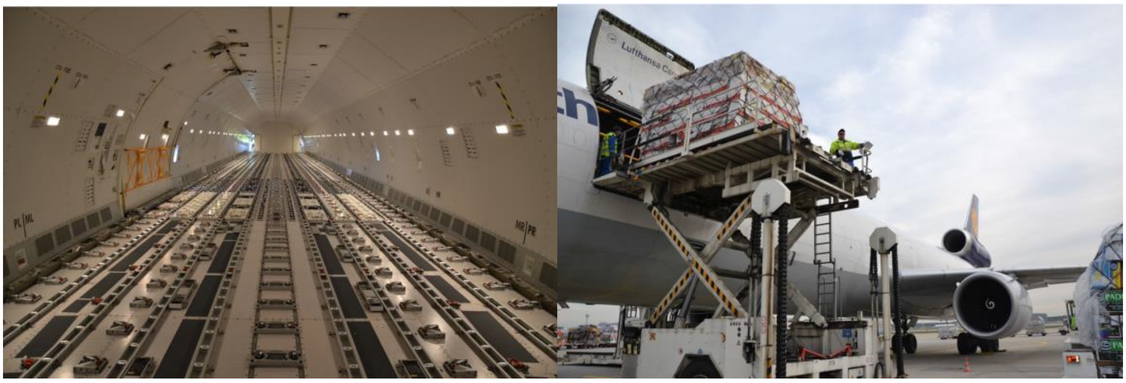


Figure 1.3 - Cargo loading

When the ULDs are placed on special designated cargo positions and they are locked to the floor by special latches. The ULDs are attached to the floor by special XZ latches, that consist of an aluminium frame and a pair of spring-loaded interlocking pawls.

When each ULD is in their position, the loading procedures is called for these XZ latches to be raised and locked manually. Figure 1.4 shows the XZ in the lower down position. Such position allows to move the cargo though cabin area and the latch does not effect on moving the cargo.

Figure 1.4 - XZ latch in lower position

Figure 1.5 shows the XZ latch in the locked position. When the ULD is moved to its position, the cargo is fixed by the help of latch.

Figure 1.5 - XZ latch in locked position

Usually passenger airplane has two separate cargo compartments on the lower deck. One is located in front of the airplane and second is behind the center of the wing box, see figure 1.6. If we are talking about cargo cargo airplane, usually the have only one main deck cargo compartment that is span along whole fuselage. As usuall most airplane compartments have only single door for loading and unloading of ULDs. According to that, loading and unloading of the cargo is usually called first in last out process (FILO). This is important for cargo airplanes since they usually have multi-leg flights, this is mean that they aren't fully unloaded in each airport and some cargo will continue the trip on the same airplane to the next airport of airfield.

Airplanes main deck compartment usually has two separate lanes. However, ULD side movement and pivots can only be done near the door where the rotating rollers on the floor are installed. The airplanes lower deck bays are usually have one full width strip that may be split to accommodate two half width outline containers. Each cargo compartment is dividing into separate cargo loading positions. The example of loading positions for the ULDs of the cargo airplane MD11F is shown in the figure 1.6.

Figure 1.6 - Layout of the loading positions of an MD11F freighter aircraft

On this scheme, a thick lines are the cargo doors that are located thorugh all fuselage length. The gray boxes – are the standards positions for loading. The alternate load positions for large ULD (CR+DR or GR+GL) and small ULD (11L/R) is shown with dashed lines.

In general, the most usual case, is standard configuration for each cargo compartment. It's mean that actual assignments of ULD type to load positions, that increases usage of space.

Other configurations may be possible, since it is depend from latches that are installed on the floor. A usuall practice is to change two basic ULD units with 1 large ULD to deliver larger cargo items in it. Other variants when the configuration is changed from standard may be a not enough quantity of required size ULDs in the airport where the cargo is loading. Alsom decreasing of the orders will also cause the change of the configureation. To keep the process of loading more simple, customers do not prefer do deviate the standard configuration for their airplane, usually the do it only if necessary.

Additionally, one of the most important parts of cargo loading process in aircraft is called calculation of weight and balance. The maximum payload that aircraft able to carry is limited. Also, the airplane structure has some stress limits. The maximum weight for each cargo load position exist. There is a maximum weight for each loading position and there also exist weight limits. Generally, there for airplanes with two decks, there are some limits for the adjacent positions or for positions above each other in main and low deck.

In addition to the weight limits also exists balance limits. Since each loaded ULD has its own weight and the most ULDs may be placed at the different loading locations in airplane, the loading distibotuin of the cargo effects on the airplane's center of gravity. As we know the center of gravity for each airplane must be in an allowed range, this range is depend on type of airplane. For example, if the airplane is too heavy in the nose part, the nose landing gear may not lift for taking-off.

Or, if for example the airplane is too heavy in the tail part, it may tip over on ground. Lateral balance also must taking into account but usually it is less important as moment is more smaller in compare to the longitudinal balance. Also, during flight pilots may change the center of gravity position by distributing the fuel between left and right fuel tanks. Unless the airplane has hard center of gravity limits, exists an optinal center of gravity for individual airplane at which decreases the fuel consumtion during flight. Most modern large cargo airplanes have optimal center of gravity position that is close to aft center of gravity limit. For example, to get high influence on the fuel consumption, Mongeau and Bes (2003) reported that they moved the center of gravity position to 75 cm on the Airbus A340 and this may lead to save 4 tonnes fuel per each 10,000 km of flight.

So, to summarize statements above, it’s clear to understand that most of the cargo that is delivered through the air is packed into ULDs such as containers or pallets.

1.5 Definition of oversized cargo problem

Usually, the cargo that is packed into ULDs is not oversized or overload.

However, all industrial, aerospace or military projects require to deliver huge elements that are oversized, or have non-stadrad dimensions, or with moved center of gravity.

If the dimensions or weight of an indivisible package is such that special technology and (or) equipment is required for its transportation, loading or unloading, then such goods are referred to as outsized / overweight cargo.

The most common goods of the outsized / overweight cargo include heavy road construction and agricultural equipment, trucks, drilling rigs, heavy machines, pipe mills, concrete plants, boiler equipment, generators, transformers, tanks for the chemical and oil refining industries, etc. The interpretation of the concepts of "oversized cargo" for aircraft category is the cargo when the dimensions of the package exceed the dimensions of the loading hatches and cargo compartments of passenger aircraft.

Wen we are talking about overweight cargo this is a cargo when the mass of one package exceeds 80 kg.

Depending on the degree of exceeding the standard overall and weight restrictions adopted for each mode of transport, the organization of the delivery may require either relatively simple technological solutions (development of special containers, special placement and fastening of cargo, the use of a specialized vehicle), or the development of an integrated project for the delivery.

Non-standard (oversized) cargo is a bulky or heavy item that, due to its technical parameters or specific features, cannot be transported in a closed road vehicle or closed container, that is, by car or train, the expamples of the oversized cargo are shown in the Figure 1.7.

Figure 1.7 - Examples of oversized cargo

Transportation of oversized cargo today is demand due to the need to transport all kinds of special, construction, agricultural and other equipment such as large tanks, parts of airplanes and rockets, parts of the engines and so on, industrial equipment and other oversized heavy cargo.

Today, the transportation of large-sized equipment is one of the main problems of the engineering enterprises. It is very important that specialized equipment is delivered to its destination in a timely manner and already in the state in which it will be used.

Oversized transportation is one of the most complex and labor-intensive. The carrier company takes a great responsibility for the safety and integrity of the cargo to the cargo owner. During transportation, the most important and significant factors are taken into account, therefore, during preparation, attention is focused on the development of the most optimal solution for the transportation of cargo, which allows you to optimize costs, as well as qualitatively carry out the task in the shortest possible time.

During the transportation of the oversized cargo, the main problem is how to load it into the aircraft. Usually, the cargo airplanes are quipped with the cargo loading devices such as telphers, cranes, winches and other.

However, the standard for example telpher with a hook couldn't provide the loading of the oversized cargo into the airplane. That's mean, that usually the oversized cargo has a moved center of gravity, and in the case of the telpher with hook, the cargo may be loading askew, and the structure of airplane and cargo will be damaged.

1.6 Solution of the loading of oversized cargo problem

To avoid the problems with the loading and unloading of oversized cargo and cargo with moved center of gravity, the model for loading of oversized cargo will be developed for the short range cargo aictaft.

The model of loading of oversized cargo will include the developing of the special device for the telpher that is called traverse.

Traverse is a connecting element between the crane hook and lifting devices (slings, grippers) necessary for even distribution of the load to all attachment points, thereby protecting the transported load from compressive forces that arise when using slings.

Hoisting traverses are used when lifting and moving bulky goods, goods with a large dead weight or a displaced center of gravity. Quite often, you can see traverses when loading machines and equipment with a shifted center of gravity, when the most efficient use of load handling devices is required, typical example of the traverse is shown on the figure 1.8.

Figure 1.8 - Typical example of traverse

The need to use lifting traverse is supported by several factors. In the first case, when the use of slings when lifting large-sized loads is impossible due to a lack of lifting height with the correct slinging angle between the branches (slings).

In the second case, the traverse is necessary when, when working with large-sized loads, significant tensile forces arise in the slings, stresses in the lifted load and attachment points.

Traverses are made of I-beams, channels, steel plates or angles, while the structure of the traverse should be simple. In the production of traverses, one of the important indicators is its own weight, since the traverses weigh a lot and eat up the potential of the lifting mechanism.

However, the decrease in the own weight of the traverse should in no way affect its carrying capacity and safety margin. The design of the crosshead is determined by the size and shape of the load to be lifted, the technical characteristics of the lifting device and the operating conditions.

Why do you need a traverse if there is a crane hook for which you can hook the load? And the fact is that there are specific cargoes. Some of them are long, such as a metal pipe.

If it is grabbed by only one point of the hook, then transportation will cause a number of problems, including those dangerous for workers. The pipe will simply spin around the grip point, presenting a serious hazard. At the same time, using two points of engagement thanks to the traverse, the transport of the length will be completely safe.

The figure 1.9 shows the attachment of the tube only with hook. This type of attachment will create some problems during the loading or unloading the tubes from cargo carbin, since the

Figure 1.9 - Attachment of tube only with hook

There are also loads with a shifted center of gravity. As a rule, these are non-standard metal structures. Again, lifting them with one grip point does not allow for safe and correct transport. With the help of several points of engagement, the load is obtained in a stable and correct position, without endangering others during lifting and movement.

Another reason for using traverse is oversized cargo. These include such structures that cannot be grabbed without the risk of one hook and slings. A stretched line can burst due to abrasion on the structure. And at any moment of transportation there is a risk that the sling will burst and the cargo will break. The lifting beam easily solves this problem, providing a reliable and correct grip at several points.

1.7 Types of traverses and their characteristics

The reasons why it is better to work with a traverse are quite large - this is the exclusion of damage to the load by slings, an increase in the working length, the elimination of pendulum oscillations of the load, ease of working with the load, the ability to lift a load of unbalanced mass, and much more.

There are main advantages of using traverse:

1. Exclusion of damage to the load by slings - this property of the traverse allows you to accurately lift the load.

2. Increase in length - this property is quite simple, the structure itself has rings on which mechanisms for lifting the load are attached, or slings with a ring, the ring is put on the hook of the lifting mechanism. The design allows lengthening the working length of the lifting mechanism.

3. Simplicity of handling the load - for each task this property can be individual, but there is one characteristic that is inherent in all traverses - this is the hook angle of the sling at - 90 °, which reduces the unnecessary load on the slings (rods) when lifting loads with a traverse.

4. The ability to lift a load of unbalanced mass - this property of the traverse is inherent in the specifics of the force of gravity, the lifted load itself looks for the optimal balance point, but when working with slings in a confined space, there is not always the possibility of unhindered passage of the load. With a traverse, finding the balance is much faster, and in the case of using a spatial traverse, which has three or more points of engagement of the load, then the displacement of the point of gravity of the load is more uniform and the spatial position of the load is most optimal for work than when working only with slings (ropes).

5. Elimination of harmonic (pendulum) vibrations - a property that is quite useful for high-intensity loading and unloading operations or work in a confined space. Harmonic vibrations, which occur under the influence of gravity, in work with a traverse shifts, and the center of mass and amplitude vibrations of the load are significantly reduced, the swing amplitude of the load becomes smaller.

There are several types of the presented devices have been developed and produced to load the bulky cargo, or the cargo that has non-standard dimensions. The traverses are differ in their design and dimensions, the number of points of engagement.

The main types of traverses are linear and speader traverses, which, in turn, can be divided according to the method of suspension on the crane hook - with suspension by the structural elements of the traverse (eye, pin) and traverse with suspension on the hook using slings.

Distinctive characteristics of the traverse are its dimensions and the possibility of hooks for lifting loads and the traverse itself, as well as an attachment element for the crane hook, lugs and rings for sling.

The types of traverses are linear and spatial structures that allow you to improve the lifting of the load due to the design ideally matched to the specifics of the load: load weight, load dimensions, purpose, industry of use, lifting equipment.

The types of traverses often correspond to the tasks in which the structure will participate - this is the movement of an oversized load, a rapid change in the dimensions of the traverse, the possibility of transporting the structure.

There are the following types of traverses:

1) A linear traverse that is attached for the center hung on the hook of the lifting mechanism and is quite wide in its application. When using a linear traverse, it is important that the load must be hung exactly in the center. In addition, there is a traverse, the lifting of which is carried out over the edges.

It is convenient to use it when the location of the center of gravity itself is not defined and asymmetrical, since it excludes overweight of the load to one side when lifting, see figure 1.10.

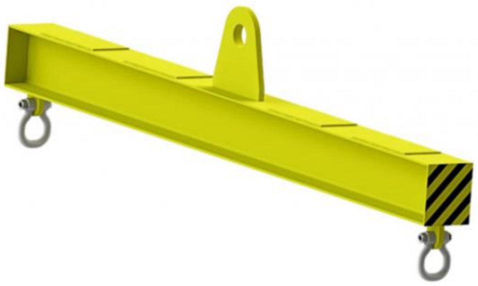


Figure 1.10 - Linear traverse

The next widespread shapes of traverses are spreaded traverses. Spreaded traverses are made in the form of simple triangular or rectangular trusses. Frame traverses are most stable when using slings to suspend them on the crane hook, due to this it is possible to lift loads of significant weight and dimensions, but, at the same time, the useful lifting height is reduced.

Spreader traverses are also divided in the following types:

1) T-shaped traverse - designed for lifting loads of varying complexity with only 3 attachment points. In this case, the load of the load is unevenly distributed. T-shaped traverses are used when lifting and moving loads with an offset center of gravity, the slinging scheme of which provides for three attachment points. The adjustable link provided in the design allows to provide optimal load on other elements of the slinging, figure 1.11 shows typical example of T-shaped traverse.

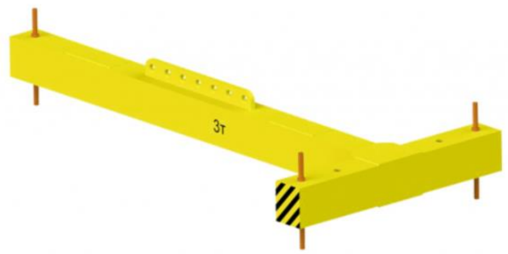


Figure 1.11 - T-shaped traverse

2) H-shaped traverse - designed for lifting loads for 4 attachment points. Lifting traverses of this type are designed for lifting various loads, the slinging scheme of which provides for fastening at four points. Also, the H-shaped traverse finds its application when moving bulky goods, which allows you to reduce the angle between the branches of the slings. This type of traverse is used to lift a container, pipe, sheet steel, ship, complex building structure, etc.

Figure 1.12 - H-shaped traverse

3) Spreaders - designed for lifting and moving large loads with a carrying capacity from 1.6 t to 32.0 t. Such traverses are suitable for lifting and moving large loads, where fastening is provided at four points, is placed on the hook of the lifting equipment either by the eye, pin or by rigid and flexible rods. As a rule, they move and lift in this way: containers, industrial equipment, vehicles, etc.

Figure 1.13 - Spreader traverse with 4-point attachment

Conclusion to the part

Cargo carriage with the number of strict recommendations and rules for delivering goods, with the implementation of unigue automated system for aircraft weight balance, the usage of different types of ULD, pallets, loading equipment has some hold loading risks in operation. Among them are the next: holds are not correct loaded by the crew, how it was provided in the instructions; when the loading is not satisfy to the trim sheet and mass and balance limits which have to be checked; the load is not fixed or restrained appropriate; unauthorised items are loaded; aircraft structure is damaged by the mechanised loading equipment.

The aim of presented work is the preliminary design of cargo aircraft for short-haul transportation with the conceptual design of the loading equipment for the oversized cargo and for the cargo with shifted centre of gravity.

Object of study of presented work is the loading process of cargo items into the aircraft by special unique equipment.

Subject of study – is the safe operation of aircraft with minimum hold loading risk of oversized cargo from mechanised loading equipment.

Taking into account the actuality of the problem, the next tasks will be investigated in the presented work:

- investigation of air transportation safety; air cargo handling requirements, air cargo types.

- preliminary design of cargo aircraft for short-haul goods traffic;

- conceptual design of loading eguipment for the safe carriage of oversized cargo without additional ground vehicles.

PART 2. PRELIMINARY DESIGN OF SHORT RANGE CARGO AIRCRAFT

2.1 The analysis of prototypes and choice of design parameters

The one of the main parts of master thesis is to perform aircraft preliminary design. The first part of work is to select data that is based on analysis of the prototypes. Initial information about prototypes is shown in the table 2.1. As prototypes for future aircraftdesigned were choosed the following airplanes in short-range class: AN-12, AN-148-100, CRJ-900, and AN-178. To be consistent with master thesis task, the designed airplane should be short range cargo transport airplane that can carry up to 16 tons of cargo.

Statistic data of airplanes flight performances and some geometric characteristcs of prototypes are shown in the tables 2.1 and 2.2.

Table 2.1 - Technical data of prototypes

Parameter	Prototype			
	AN 148-100A	CRJ-900	AN-178	AN-12
Purpose of the aircraft	passanger	passanger	cargo	cargo
Crew/flight attend. persons	2/2	2/2	2/2	2/2
Maxinum payload, kg	9000	10319	18000	13080
Cruise speed., km/h	820	848	830	570
Flight altitude, m	11000	12500	12200	10200
Maximum range, km	1920	2955	5500	3600
Thrust to weight ratio, N/kg	3,25	3,19	3,66	3,8
Takeoff distance, m	1580	1779	2500	1230
Landing distance, m	1600	1596	2300	1125
Take of weight, kg	38550	36514	51000	61000
Type of engine	2ТРДД	2ТРДД	2ТРДД	4ТВД
Takeoff thrust кN, кVт	62,7	58,4	77,8	88,9
Pressure ratio	21	23,09	21	7,32
Bypass ratio	4,8	5,13	5,6	2,2

Table 2.2 - Geometrical parameters of the prototypes

Parameter	Aircraft			
	AN 148-100A	CRJ-900	AN-178	AN-12
Fuselage cross-section	Circular	Circular	Circular	Circular
Fuselage diameter	3,35	2,69	3,55	4,5
Fineness ratio of the fuselage	7,82	11,8	8,38	5,04
Sweep back angle 1/4 chord	25	24	25	24
Wing aspect ratio	9,5	9	10	11,9

Next step of the preliminary design is weight estimation, choice of engines and wing loading optimization. After the first iteration of masses and conceptual design ohase of the designing aircraft we are able to start preliminary design of fuselage, tail, wing, and landing gear, the next phase – is to evaluate wing loading and the required area of a wing, that can generate enough lift to withstand aircraft weight in all regimes of V-n diagram. After that, correct position of the wing to fuselage, its centre of gravity and aerodynamic centre, the area of tail empenage are also take part in airplane stability.

On the base of prototypes layout, the designed airplane will be high wing; with T-type shape of tail unit; 2 turbojet engines located under the wing on pylons, landing gear with tricycle scheme, that retracts into fuselage. The following scheme provides high designed efficiency of high lift devices, easy airplane trim during the flight, high location of tail unit, provides decrease of destabilizing moment during flight; reduce the area of the vertical and the horizontal stabilisers. The initial data of designed airplane is represented in Appendix A, this initial data was received by computer program at the department of Aircraft Design.

2.2 Aircraft geometry calculation

2.2.1 Wing design

Geometrical parameters of the airplane wing are determined mainly based on the airplane take-off mass m_0 and specific load than is applied to the wing surface P_0.

To determine wing area the following formula is used:

$$Sw = \frac{m_0 \times g}{P_0},$$

where m_0 – is a take of mass; kg;

g= 9,81 m/s^2- is gravity acceleration;

P_0 – is wing specific load during airplane take off; Pa.

$$S_{wfull} = \frac{m_0 \cdot g}{P_0} = \frac{53122 \cdot 9.8}{4223} = 87.32[m^2]$$

Wing span could be calculated by the following formula:

$$l = \sqrt{S_w \cdot \lambda_w} = \sqrt{87.32 \cdot 9.58} = 28.92[m]$$

where λ_w – is a wing aspect ratio.

The tip and root chords of wing are obtained be the following formulas:

$$b_o = \frac{2S_w \cdot \eta_w}{(1+\eta_w) \cdot l} = \frac{2 \cdot 87.32 \cdot 4.05}{(1+4.05) \cdot 28.92} = 4.84[m]$$

where η – is wing taper ratio;

$$b_t = \frac{b_o}{\eta_w} = \frac{4.84}{4.05} = 1.19[m]$$

The position of the rear and front spars to leading edge of wing is choosed according to relative coordinates $\overline{X}_1$= 0,2 ; $\overline{X}_2$= 0,6.

The root chord relative coordinates are:

$$X_1 = \overline{X}_1 \times b_0 = 0,2 \times 4,84 = 0,968[m]$$

$$X_2 = \overline{X}_2 \times b_0 = 0,6 \times 4,777 = 2,904[m]$$

The tip chord relative coordinates are:

$$X_1 = \overline{X}_1 \times b_K = 0,2 \times 1,19 = 0,238[m]$$

$$X_2 = \overline{X}_2 \times b_K = 0,6 \times 1,18 = 0,714[m]$$

To determine the wing mean aerodynamic chord (MAC, b_{mac}) the geometrical method was used (figure 2.1), b_{mac}= 3,341 m.

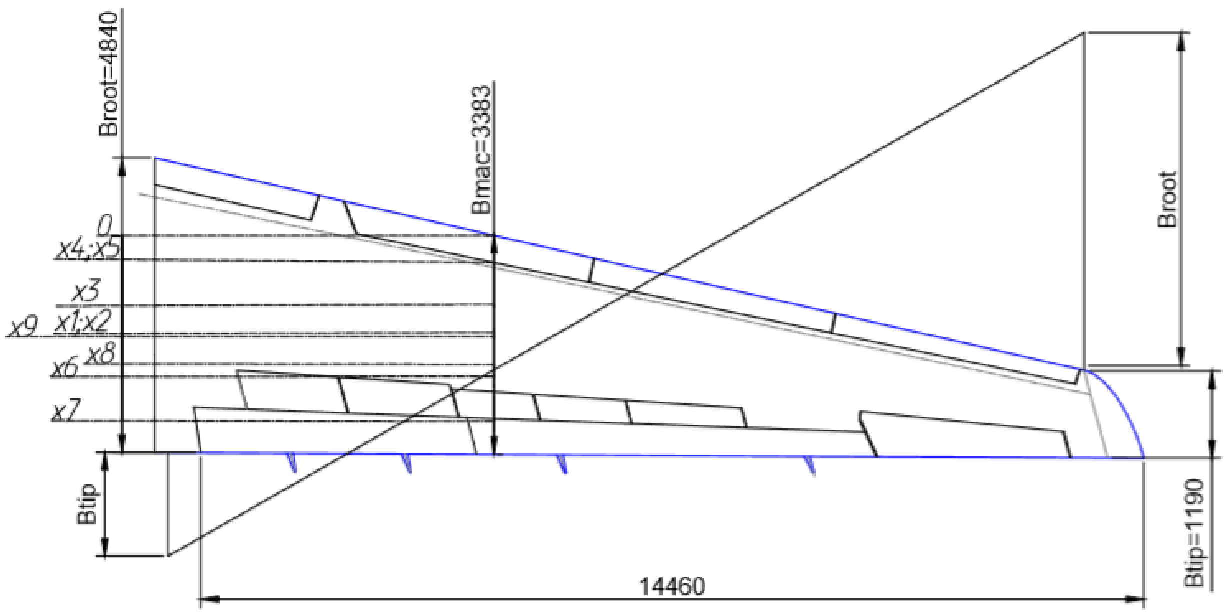


Figure 2.1 – Wing mean aerodynamic chord

To be consistent with analysis of statistic data of the prototype airplanes, and based on accepted initial source data, we take the relative thickness of aifoil $\bar{c}_i$=0.118

So, airfoil thickness in a root and tip parts equal:

$$c_{root} = \overline{c}_{root} \times b_0 = 0,118 \times 4,84 = 0,571[m]$$

$$c_{tip} = \overline{c}_{tip} \times b_0 = 0,118 \times 1,19 = 0,14[m]$$

For designing airplane, double-slotted flaps without the aerodynamic balance were choosed for the high lift devices. The main aim of high lift devices is to provide extra lift force while take off and landing.

The slats will extend through the whole length of leading edge of a wing. The slats area is calculated by the following equation: S_{slat}=0.1 S_{wing}

$$S_{slat} = 01 \times 87,42 = 8,742[m]$$

The flaps area is found by the following equation S_{flaps}=0.17 S_{wing}

$$S_{flaps}=0.17 *87,42=14,86[m]$$

The wing trailing edge is filled not only with flaps and additionally with ailerons at the wing tip.

To find the span of the aileron we use the following formula:

$$l_{ail} = 0.375 \cdot \frac{l_w}{2} = 0.375 \cdot \frac{28.92}{2} = 5.72[m]$$

Aileron area is calculated as follows:

$$S_{ail} = 0.065 \cdot \frac{S_w}{2} = 0.065 \cdot \frac{87.32}{2} = 2.83[m^2]$$

Approximate aileron range deflection is upward $\delta_{ail} \geq 20^\circ$ and downwards $\delta_{ail} \geq 10^\circ$

2.2.2 Fuselage layout

To choose correct size and shape of the designing fuselage, it is required to follow the requirements of aerodynamics. The main requirements of aerodymanic are cross-sectional area streamlining.

When we are talking about subsonic airplanes (V < 800 km/h) the drag of shock wave is not so important. So, the shape must be chosed from condition to receive lowest values according to friction drag C_{xf} coefficient and the form drag C_{xp}.

For transonic airplanes the nose part must be determined as follows: L_{ns}=(2...3)D_f , where D_f – diameter of fuselage.

Additionally, it is required to take into account the strength requirments.

In order to receive the minimum weight, it was determined that best variant of fuselage cross section is the round cross section. So, thickness skin of fuselage is lowest.

The main geometrical parameters: diamater of fuselage D_f; length of fuselage L_f; - fuselage finenness ratio:

$$\lambda_f = \frac{D_f}{L_f}.$$

- fineness ratio of nose part:

$$\lambda_{ns} = \frac{l_{ns}}{D_f}.$$

- finenness ratio of tail part:

$$\lambda_{tp} = \frac{l_{tp}}{D_f}.$$

where l_{tp} and l_{np} – the lengthes of tail part and nose part. The fuselage length is calculated with taking into account designed aircraft scheme.

There are following fuselage parameters:

$$l_f = \lambda_f \cdot D_f = 8 \cdot 3.35 = 26.8[m]$$

$$l_{np} = \lambda_{np} \times D_f = 3{,}1 \times 3{,}35 = 10{,}3[m]$$

$$l_{tp} = \lambda_{tp} \times D_f = 2{,}1 \times 3{,}35 = 7{,}035[m]$$

Additionally, it’s necessary to make minimum fuselage mid-section S_{ms}. For the cargo airplane, mid-section is depending from cargo cabin size.

Crew cabin area must take as less area as possible on the airplane. However, on other hand cabin should provide comfortable conditions for airplane crew operation. Pilot’s working places have to meet some requirements. Crew’s places have to provide perfect view from cabin. The crew cabin dimensions depend on number of pilots. Nowadays the airplane flight crew consists from two or three pilots. The crew includes of: first pilot (captain) and co-pilot. The flight compartment for crew is separated from cargo cabin by a special devider with lockable door. The accompanying persons of cargo transportation could be accommodated in creq cabin or close to it. Their seats could be similar to the seats of flight attendance or to passengers seats with safety belts and shoulder harness straps.

2.2.3 Tail unit design

The main goal while calculating the aerodynamic layuout is to find location of tail empennage. In order to provide longitudinal stability of aircraft it's necessary to locate airplane center of gravity at the front focus of the airplane.

The arm between aerodynamic centre of tail surface and the centre of gravity, located at mean aerodynamic chord (MAC) that shows efficiency of longitudinal stability and balance could be evaluated from the next equation:

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

where $m^{Cy}{}_x$ coefficient of moment, $x_{T.}$,x_F, - airplane center of gravity and focus. The airplanes have neutral longitudinal static stability if $m^{Cy}{}_x$ equals to 0.

According to the analysis of statistic data of prototype airplanes, we have:

$$S_{HTU} = \frac{b_{MAC} \cdot S_w}{L_{HTU}} \cdot A_{HTU} = \frac{3.38 \cdot 87.32}{9,46} \cdot 0.55 = 18.87[m^2]$$

$$S_{VTU} = \frac{l_{w\cdot} S_w}{L_{VTU}} \cdot A_{VTU} = \frac{28,92 \cdot 87.32}{9.46} \cdot 0.09 = 21.15[m^2]$$

Length of tail and nose parts, wing location, sweep back angle, stability and controls of airplane effects on length of horizontal and vertical stabilizer. In first iteration, we may take it like the next $L_{HTU} \approx L_{VTU}$.

Elevator area is calculated as follows:

$$S_{el} = 0.2765 \cdot S_{HTU} = 5.21[m^2]$$

Rudder area is calculated as follows:

$$S_{rud} = 0.2337 \cdot S_{VTU} = 4.94[m^2]$$

The tail unit span and wing span are usually connected by the static data of aircraft.

$$L_{HTU}=(0,32\ldots0,5)\ l_W= 0,323\times28,95 = 9.3[m]$$

There are several factors influence on height of vertical stabilizer such as wing to fuselage position and location of engines. The geometrical paramenters of a tail unit are the next:

The taper ratio of vertical and horizontal stabilizers may be taken from the range η_{HTU}= 2...3 and η_{VTU}= 1...3,3. Based on analysis of statistic data of prototypes airplanes we take η_{HTU} = 2,51 and η_{VTU}= 1,367.

For the subsonic airplanes the aspect ratio of the tail is calculated as follows range $\lambda_{VTU} = 0,8\ldots1,5$ and $\lambda_{HTU} = 3,5\ldots4,5$

Based on analysis of statistic data of prototypes we consider $\lambda_{VTU} = 0,95$ and $\lambda_{HTU} = 4,5$

To calculate the chords of root and chord of tip of the tail unit b_{tip}, b_{root} the following formulas are used:

For the horizontal tail unit:

$$b_{0HTU} = \frac{b_{0HTU}}{\eta_{HTU}} = \frac{2.89}{2.51} = 1.15[m]$$

$$b_{0HTU} = \frac{2S_{HTU} \cdot \eta_{HTU}}{(1+\eta_{HTU}) \cdot l_{HTU}} = \frac{2 \cdot 18.87 \cdot 2.51}{(1+2.51) \cdot 9.32} = 2.89[m]$$

For vertical tail unit:

$$b_{0VTU} = \frac{b_{0VTU}}{\eta_{VTU}} = \frac{5.32}{1.367} = 3.89[m]$$

$$b_{0VTU} = \frac{2S_{VTU} \cdot \eta_{VTU}}{(1+\eta_{VTU}) \cdot l_{VTU}} = \frac{2 \cdot 21.15 \cdot 1.367}{(1+1.367) \cdot 4.59} = 5.32[m]$$

In the first approach the airfoil relative thickness is choosed as follows: $\overline{C}_{em} \approx 0,8\,\overline{C}_{w}$. In case of horizontal stabilizer will be attached on fin, we suggest $\overline{C}_{em} = (0,08\ldots0,1)$. For our designing airplane we assume $\overline{C}_{em} = 0,1$.

Usually the sweep back angle of tail unit is near 3 - 5º bigger than wing sweep angle. This is done to make sure that airplane will be controlled when form drag is initiated on a wing. So, for the designing aircraft we take the next parameters of sweep back angle of horizontal unit $\chi_{HTU}=32^{\circ}$, and sweep back angle of vertical tail unit $\chi_{VTU}=40^{\circ}$.

2.2.4 Selection of engine for designing airplane

While reviewing thrust-to-weight ratio of prototypes engines, the same value of 3.2 was chosen for designing airplane. On a base of required thrust-to-weight ratio, distance for takeoff and landing, engine parameters from initial data, it was selected turbojet engine D436T1 (figure 2.2), the main characteristics of such engine are shown in the table 1.4.

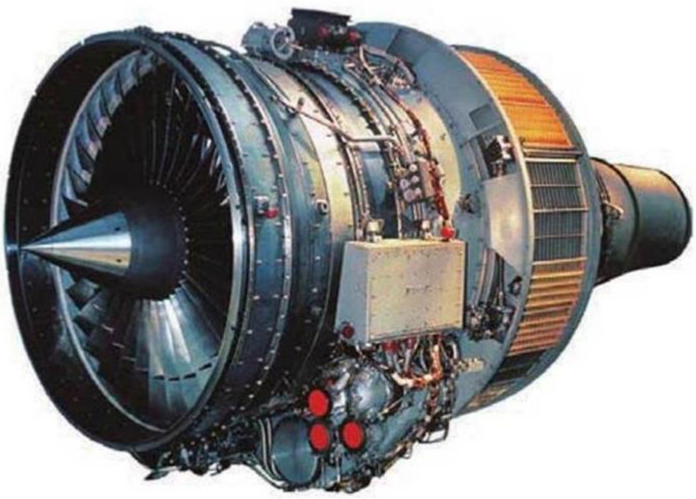


Figure 2.2 –Engine D436T1

Table 1.4 - D436T1 main characteristics

Engine data	Units of measurement	Value
Type of engine	-	D436T1
Take of power	kN	73,57
Power in cruise flight mode	kN	14,71
Specific fuel consumption on take off mode	kg/N×hour	0,037
Specific fuel consumption in cuise flight mode	kg/N×hour	0,062
Engine pressure ratio	-	24
Dry engine mass	kg	1450
Bypass ratio	-	4,95

2.2.5 Landing gear design

For the designed airplane it was suggested to take tricycle retractable landing gear scheme. It’s the most common type of landing gear design. During takeoff all airplane’s weight is applied to main wheels, additionally this scheme has increased lateral stability on ground.

While designing of airplane, when center of gravity position is unknown, and there is no general view of the designed airplane, we are able to calculate following parameters of the landing gear:

Distance from centre of gravity position to main landing gear approximately may be calculated as follows:

$$e = 0.2673 \cdot b_{MAC} = 0.2673 \cdot 3.38 = 0.903[m]$$

Landing gear wheel base was found by following:

$$B = 0.4526 \cdot L_f = 0.4526 \cdot 26.8 = 12.129[m]$$

Nose langing gear is able to carry from 6 to 10% of total airplane weight, nose langing is calculating as follows:

$$d_{ng} = B - e = 11.226[m]$$

The wheel track of the designed airplane is found by the follow formular:

$$T = 0.6072 \cdot B = 0.6072 \cdot 12.129 = 7.36[m]$$

The landing gear tires size depends on loads act on it, takeoff and landing speed of the aircraft. For the tires of nose landing gear wheel it is considered the dynamic loads.

The pressure in tires depends on the type of runway where airplane will be operated.

The loads applied to the airplane wheels can be calculated:

For the nose landing gear the load is:

$$P_{NLG} = \frac{(9.81 \cdot e \cdot k_g \cdot m_0)}{(B \cdot z)} = \frac{(9.81 \cdot 0.903 \cdot 1.8 \cdot 53122)}{(12.129)} = 71924.008[N]$$

For main landing gear the load is:

$$P_{MLG} = \frac{(9.81 \cdot (B - e) \cdot m_0)}{(B \cdot n \cdot z)} = \frac{(9.81 \cdot (12.129 - 0.903) \cdot 53122)}{(12.129 \cdot 2 \cdot 2)} = 219240.5[N]$$

Where K_g - is dynamic the coefficient and is 1.5-2.0.

The tire dimensions for designed airplane are shown in table 2.5.

Table 2.5 –Tires geometry for landing gear design

Main gear		Nose gear	
Tire size	Ply rating	Tire size	Ply rating
1244x 431	32	990x330 mm	16

The pressure in aircraft tires are usually close to 13 bar (200 psi, 13 atm).

2.3 Airplane centre of gravity calculation

At the stage of preliminary design, when the geometrical parameters are calculated, when schemes of the airplane parts were choosed, the next aim is to evaluate the weight of main components of airplane based on the statistical data. The airplanes weight is devided into weight of the fully loaded airplane and empty weight of airplane. It’s normal practice to combine different equipment, systems and components of the airplane.

The main requirements for the airplane layout are the following: each cargo of airplane should be located in that way where it will be most useful. The airplane layout must provide the suitability maintanance and control of the units and systems, also to provide comfortable installation and repairing of units and parts; layout has to provide theconvenience of general structure assembling; airplane structural layout must provide as more less weight with more sufficient durability and strength.

2.3.1 Trim sheet of equipped wing

Mass of equipment that is located in the wing, mass of the total wing structure, and fuel, are all others parts of systems are included in the equipped wing mass. The start calculations of the center of gravity coordinates definitions we need to put projection of MAC to root of the wing, with origin (or “0” coordinates) will be in the leading edge of a wing mean aerodynamic chord. Positive direction of coordinated will be in the airplane tail part. The results of trim sheet calculations of the equipped wing is represented in table 2.6.

The center of gravity coordination of equipped wing with all masses and masses of systems parts are found as ratio of sum of all mass moments to the sum of the masses of the equipment and wing structure:

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

Table 2.6 – Trim sheet of equipped wing

N	Name	Mass		C.G. coordinates x_i (m)	Moment $m_i x_i$ (kgm)
		Units	total mass m_i (kg)		
1	Wing structure	0.11993	6370.92	1.4196	9044.16
2	Fuel system, 40%	0.00152	80.75	1.4196	114.62
3	Control system, 30%	0.00219	116.33	1.014	117.96
4	Electrical equip. 10%	0.00208	110.49	0.338	37.34
5	Anti-icing system 70%	0.01197	635.87	0.338	214.92
6	Hydraulic system, 70%	0.01358	721.39	2.028	1462.99
7	Engines	0.08915	4735.82	2.65	12549.93
8	Equipped wing without fuel	0.24042	12771.59	1.8433	23541.95
9	Fuel	0.13088	6952.60	1.4534	10104.91
	Equipped wing	0.3713	19724.19	1.7058	33646.87

2.3.2 Trim sheet of equipped fuselage

The procedure of the centre of gravity calculations of equipped fuselage is similar to the procedure for a wing calculations. The origin of the coordinate system on X axis will be the nose of the fuselage, and all centers of any masses will take positive coordination.

To provide longitudinal balance of the aircraft we shoud choos correct position of the wing to the fuselage. It is can be possible by the performing mass moments equiation for equipped wing and equipped fuselage. The balance equiation is the next:

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

X_{MAC} - is the distance from the nose of the fuselage to the leading edge of a wing mean aerodynamic chord.

$$X_{MAC} = \frac{m_f x_f + m_w \cdot x_w^{/} - m_0 C}{m_0 - m_w} = 10.9 \,.$$

where: m_f - mass of the equipped fuselage.

m_w - mass of the equipped wing.

$C = (0,28...0,32) \cdot b_{mac}$ – coefficient, which can be found like the length from MAC leading edge to airplane center of gravity.

The equipped fuselage center of gravity calculations are represented in table 2.7.

Table 2.7 - Centre of gravity of equipped fuselage

	Objects	Mass		Coordinates of C.G., m	Mass moment, kgm
		Units	Total, kg		
1	Fuselage	0.12476	6627.5	13.41	88881.41
2	Horizontal tail unit	0.0174	928.04	0.91	844.51
3	Vertical tail unit	0.02031	1078.9	2.07	2233.33
4	Anti-icing system, 15%	0.00256	135.99	21.45	2917.03
5	Air-conditioning 15%	0.00256	135.99	13.41	1823.79
6	Heat and sound isolation	0.0062	329.35	13.41	1823.79
7	Control system, 70%	0.00511	271.45	13.41	3640.46
8	Hydraulic sys30%	0.0058	308.1	18.77	5783.17
9	Electrical eq, 90%	0.0187	993.38	13.41	13322.23
10	Radar	0.0059	313.41	1.081	338.8
11	Air-navig. system	0.0088	467.4736	1.88	878.85
12	Radio equipment	0.0044	233.73	1.081	252.66
13	Instrument panel	0.0103	547.15	2.58	1411.66
14	Seats of crew	0.00056	29.96	2.78	83.29
15	Seats for accomp.person	0.00037	19.97	3.6	71.9
16	Cabin equipment	0.0006	31.87	6.26	199.52
17	Cargo equipment	0.02845	1511.32	23.59	35655.08
18	Non typical eq.	0.0037	196.55	896	1761.1
19	Service equipment	0.01594	846.76	6.99	5918.88
20	Nose landing gear	0.00297	157.77	2.78	438.6
21	Main landing gear	0.04153	2206.15	12.4	27356.34
	Equipped fuselage without payload	0.26286	13963.94	11.65	162754.77
22	Cargo	0.295	15670.99	13.6	213125.46
23	Crew	0.00564	299.6	2.78	832.91
	Total	0.9999	53122	18.25	608589.72

2.3.3 Aircraft centre of gravity range for different types of loading

At the current stage of airplane preliminary design we have already found wing attachment with the fuselage. We have already calculated the fuselage and wing centers of gravity. So, now we need to find the centers of gravity for the different types of airplane loading and flight regimes. Airplane center of gravity is relative coordination of centre of gravity position related to the leading edge of mean aerodynamic chord projection and such relation is showed in the percentage. The center of gravity calculations are shown in tables 2.8 and 2.9.

Table 2.8 - Centre of gravity summary list

Name	Mass $m_{i,}$ kg	Coordinates, m	Mass moment, kgm
Equipped wing	12771.59	13.84	176867.3
Nose LG (retracted)	157.77	1.78	280.83
Main LG (retracted)	2206.15	12.4	27356.34
Fuel	6952.6	12.37	86003.75
Equipped fuselage	13963.64	11.65	162754.77
Cargo	15670.99	13.6	213125.46
Crew	299.6	2.78	832.91
Nose LG (opened)	157.77	2.78	438.6
Main LG (opened)	2206.15	12.4	27356.34

Table 2.9 Centre of gravity range for different aircraft load cases

№	Loading case	Mass, kg	Mass moment, кg m	Centre of the gravity, m	Centre of gravity from MAC,%
1	Take-off mass (landing gear opened)	53122	664159.15	12.76	22.53
2	Take-off mass (landing gear retracted)	53122	664121.38	12.76	22.51
3	Landing variant (landing gear opened)	48422.2	603382.24	12.46	15.48
4	Transportation variant (without payload)	36351.38	454095.91	12.49	16.39
5	Parking variant (without fuel and payload)	29099.16	367417.02	12.62	18.37

Conclusion to the part

The preliminary design of a short range cargo airplane with the cargo capacity up to 16 tons was designed in this part. It was considered the aerodynamic scheme, the main parts and structural elements of the airplane.

So, in result of this part of master thesis we develop preliminaty design of the airplane with 28,92 m of wing span, the length of fuselage is equal to 26,8 m and the fuselage diameter is 3,35 m. In order to provide required thrust for different regimes of flight, it was choosed D436T1 engine. This engine has enough thrust-to-weight ratio, low fuel consumption, and low noise and emmisions levels. Additionally, the most forward amd most aft positions of center gravity were calculated. We receive the most forward position of centre of gravity - 15,48 % from leading edge of mean aerodynamic chord landing case of loading, most aft centre of gravity is 22,53 % for take-off regime of flight. Due to the presented data we are sure that all airplane’s masses are in the equilibrium.

The final results of the preliminary design phase if the drawings of general view of the aircraft and fuselage layout with cargo cabin design.

PART 3. CONCEPTUAL DESIGN OF LOAD HOIST WITH TRAVERSE

3.1. Description of the load hoist

Load hoist is a cargo equipment that is designed to load and unload different types of load, such as containers, pallets, mono-loads, or oversized cargo. This device is developed to load cargo from cargo location are and deliver the cargo across aircraft cargo cabin. The movement of the cargo is carried out on special rails that are mounted under the cargo compartment ceiling. The transverse movement of cargo is carried out by two trolleys mounted on the frame of on board loading loader. The load hoist of the cargo loading mechanism can provide the following movement of the cargo: lifting the cargo and moving it through the cargi cabin. The lifting mechanism is a load hoist associated with a double tackle.

During designing of this device, it is necessary to calculate the conditions where the load hoist will be used.

The load hoists have the following general characteristics:

- Maximum height of lifting up to 100 meters;
- Weight of cargo from 0.6 to 100 tons;
- Lifting speed of cargo from 4 to 16 m/min.

There are several types of load hoists: a) movable, c) stationary, b) explosion proofed, d) with decreased overhall height (Fig 3.1).

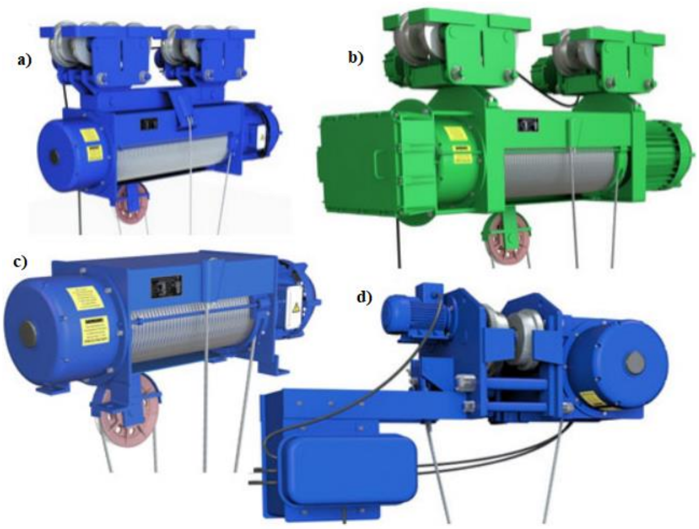


Figure 3.1 – Types of load hoists.

Load hoists are the devices that work independently, this is mean that these cargo load devices can lift crgo in vertical direction, and move the cargo in horizontal plane.

Load hoists are designed to load cargo without help of nya other devices and very quickly.

These devices can be used in "hard" conditions, where the temperatire is in range from -40°C to +40°C.

To be consistent of the required purpose of the load hoist, the designed device should meet the following parameters: carrying cargo capacity approximately 5 tons; speed of lift approximatelly 20 m/min; height of lift approximately 3.5 meter, movable speed approximatelly 25 m/min.

3.2. Design of the rope

The one of the important elements of the loading mechanisms is the rope. The rope has an high influence on the safery of loading process.

It is very important to select correct rope design and choose correct attachment of the rope to the drum. This will decrease the wear of the rope and a drum.

To calculate the tension of the rope, the following formula should be used:

$$F_{\max} = \frac{G}{Z_{n.r.} u_n \eta_n \eta_{n.b.}} \; .$$

G is a weight of our cargo =50 кN;

$Z_{n.r.}$ is a quantity of ropes that winded on drum, $Z_{n.r.}$=2;

u_n is a mechanical advantage of block/tuckle;

η_n is an efficiency of block/tuckles;

$\eta_{n.b.}$ is a rope balancer efficiency.

We choose $Z_{n.r.}$=2; u_n =4; η_n=0,94; $\eta_{n.b.}$=0,96.

The maximum tension force of the rope is:

$$F_{\max} = \frac{50}{2 \cdot 4 \cdot 0,94 \cdot 0,96} = 6,9[kN]$$

It is necessary to choose type of by the following conditions:

$$F_{\max} z_p \leq F_{break} \,.$$

Z_p is a coefficient of movable ropes from M2 classification of mechanisms, and it's located in the table 3.1; F_{break} is a breakage force of rope.

Table 3.1- Rope safety factors

Class of mechanism	Movable ropes	Stationary ropes
	Z_p	
M1	3.15	2.50
M2	3.35	2.50
M3	3.55	3.00
M4	4.00	3.50
M5	4.50	4.00
M6	5.60	4.50

To be consistent with [19] 6 groups of the operating modes are considered. Each of this mode is characterized by definite combination of classes for use of mechanism and loads that will applies on mechanism. To achieve the normal time of mechanism operating, we have to choose corret class of rope. Mechanism class and characteristics are shown in table 3.2, load class characteristic is shown in table 3.3.

Table 3.2 – Mechanism load classes

Class of usage	How often used
A0	Rarely
A1	Irregular
A2	Regular (low intensity)
A3	Regular (mid intensity)
A4	Irregular or regular
A5	Intensive
A6	Very intensive

Table 3.3 – Loading classes

Loading class	Characteristic of loading	
	Lifting	Movement
B1	Usual minimal loads; rare maximum loads.	Rare brakes/ brakes, significant work/idle run; low mass, low production intensity
B2	Medium/minimal loads; maximum loads rare.	Regular starts/brakes, small work/idle run; insignificant cargo mass.
B3	Medium/minimal loads; minimum loads episodic.	Regular starts/braking, small work/idle run, relative large cargo mass.
B4	Maximum loads and close to maximum; episodic average loads	Frequent starts/braking and some pause to rest, large cargo mass

With the help of tables above, the following characteristics were choosed: A1 - irregular work, since the cargo aircraft may have one flight in week. B3 - medium cargo loading. To be consistent with table 3.4 we can determine the mechanism load classification.

Table 3.4 – Mechanism load classification

Class of usage	Service life, hours	Class of loading			
		B1	B2	B3	B4
A0	Up to 800	1M	1M	1M	1M
A1	800 -1600	1M	1M	2M	3M
A4	6300 -12500	3M	4M	5M	6M

As a result we can decide that our device has 2M mechanism classification. Lifetime is qual to 1600 h. For 2M classification of mechanism our Z_p is 3.35.

This was calculated to find approximate service life of our mechanism.

$$6,9 \cdot 3,35 = 23,12 \text{ кN} \leq F_{break} \ .$$

To be consistent with conditions mentioned in [20] was choosed 2 lay rope type with designation ЛК-Р (Fig 3.2). The material 6.2-Г-1ОЖН1960 is taken for the rope, diameter d_r= 6.2 mm. Designation Г shows that rope is appropriate to cargo mechanism, Н shows that rope - non rotaiting, ОЖ shows the material of rope: zink-coated, marking group - 1960.

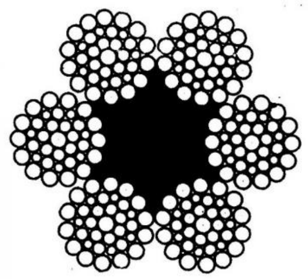


Figure 3.2 – Rope cross-section.

We can see that this rope includes large amount of wires with small diameter and they have high fatigue value when they will bend on mechanism blocks.

3.3. Design of the drum and sheave

Drum is cylindrical structure that is covered on outside surface with channels for the rope attachment. The size of channels or grooves depend on rope diameter that will be attached. The quantity of channels depends on number of rope that will be stucked. The upper lifting device which is designed for high lifting height will have longer rope and drum for this purpose also be longer. length for such device will be longer.

Most wear resistance part in the upper loading device is drum.

Balance sheave - simple mechanism with the wheel form with channel in circle where a flexible ropes are thrown.

There are two types of blocks: guiding and driving. Guide block is used to vary the direction of ropes during lifting procedure. To transmit torque berween the shafts, the driving block used.

To calculate diameter of blocks we used the following formula:

$$D_{rbl} \geq h_3 d_\kappa .$$

h_3 is coefficient diameter of rope balancer.

The h_3=12,5 shown in table 3.5 for M2 classification.

Table 3.5 – Coefficient of diameter for drum

Mechanism classification	Coefficient diameter		
	h1 drum	h2 sheave	h3 sheave balancer
M1	11.2	12.5	11.2
M2	12.5	14.0	12.5
M3	14.0	16.0	12.5
M4	16.0	18.0	14.0
M5	18.0	20.0	14.0

So, it can be the next value $D_{rbl} \geq 12,5 \cdot 6,2 = 78$ [mm]

Due to nominal diameter: D_{rbl} =160 mm. Depth of a groove for sheave is h=(1,4…1,9)6,2 = 8,7…11,8 mm.

Groove base radius is R=(0,53...0,56)6,2=3,3...3,5 [mm].

From this calculation we take depth of groove - 10 mm and radius 3.5 mm.

To calculate drum diameter we use the following formula:

$$D \geq h_1 d_k .$$

h_1 – drum diameter coefficient of and it’s taken from table 3.5.

h_1=12,5 for M2 classification.

$D \geq 12,5 \cdot 6,2 = 78$ [mm]

The nominal diameter of drum was already choosed: D = 160 mm.

Second characteristics of drum is a length. The length is calculated thrugh this formula:

$$l_d = Z_{n.r.} l_n + l_1 + 2l_0 + \left(Z_{n.r.} - 1\right) b \, .$$

l_n – length between axes of the external rope wind of 1/2 drum;

l_1 – drum length for the rope attachment;

l_0 – length from axes of rope wind end to drum edge;

b – length of the non groove middle part of drum.

Distance between exes of the external rope wind is calculated as follows:

$$l_n = t\left(Z_c + Z_1\right).$$

$t \approx \left(1{,}1\ldots1{,}3\right) d_k = \left(1{,}1\ldots1{,}3\right) 6{,}2 = 6{,}82\ldots8{,}06$ mm, take middle; t=7.

$Z_к$ – winding number of rope to lift cargo for the required height.

$Z_1 \geq 1{,}5$ of full winding.

This requirement shows, lower position of cargo. Value of windings on rope musn’t be less 1,5 of fullwinding. So, we take value – 2.

$$Z_c = \frac{L_c}{\pi D}.$$

L_c is rope length, that winding on ½ of drum.

$$L_c = u_b H \, .$$

H – lifting cargo height;

u_b – block/tuckle mechanical advantage;

The result are:

$$L_c = 4 \cdot 3.5 = 14 \text{ [mm]}$$

$$Z_c = \frac{14 \cdot 10^3}{3,14 \cdot 160} = 28$$

$$l_n = 7(28 + 2) = 210 \text{ [mm]}$$

$$l_1 = 3t = 3 \cdot 7 = 21 \text{ [mm]}$$

$$l_0 = 2t = 2 \cdot 7 = 14 \text{ [mm]}$$

The following requirement must be followed:

$$b \geq B_3 - 2h_{\min} \operatorname{tg} \alpha \, .$$

B_3 –length of the external sheeves of hook assembly,

B_3 = 50 mm;

h_{min} – length that is minimal between axis of drum and axis of sheeves of hook, h_{min}=600 мм;

α – is a maximum angle of inclination of the rope from the normal vector of rope to axis of drum, this must be α≤6°, we take α=1°.

$$b \geq 50 - 2 \cdot 600 \operatorname{tg} 1° = 29 \text{ [mm]}$$

$$l_d = 2 \cdot 210 + 21 + 2 \cdot 14 + (2 - 1) \cdot 29 = 498 \text{ [mm]}$$

For drum material we take steel - 35Л. This material is widely used for manufacturing of parts that operate under influence of the medium dynamic or static loads such as: balancers, gears, latches, rods, diaphragms, brackets, and so on.

3.4. Drum axis strength analysis

In order to find strength characteristics of drum it’s required to build scheme of drum and bending stress from attached ropes (F_{max}).

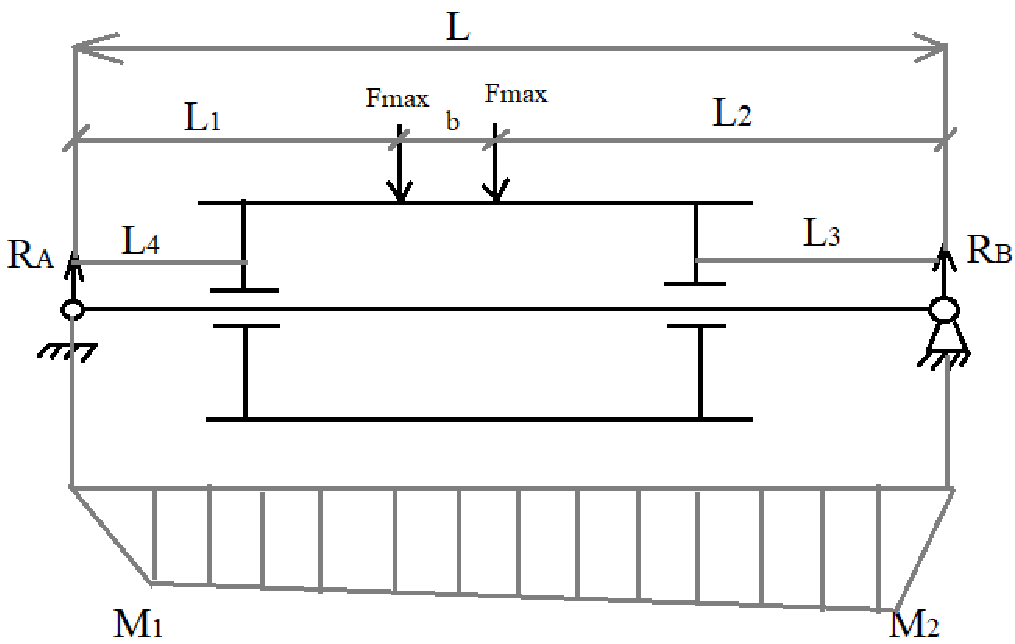


Figure 3.3 - Drum axis and loading scheme

To calculate geometrical characteristics we use the following formulas:

$$l_2 = l_n + l_0 + l_1 = 210+14+21=245 \text{ [mm]}$$

$$l_3=l_4=50 \text{ [mm]},$$

$$l = l_d + l_3 + l_4 = 498+50+50=598 \text{ [mm]}$$

To calculate reactions the following formulas are used:

$$R_A = \frac{F_{max}\left[l_2 + \left(l_2 + b\right)\right]}{l}.$$

$$R_B = 2F_{max} - R_A.$$

$$R_A = \frac{6.9\left[245 + \left(245 + 29\right)\right]}{598} = 5.98 \text{ [kN]}$$

$$R_B = 2 \cdot 6.9 - 5.98 = 7.82 \text{ [kN]}$$

To calculate bending moment the following formulas are used:

$$M_1 = R_A l_4$$

$$M_2 = R_B l_3$$

$$M_1 = 5.98 \cdot 0,05 = 0,29 [kN \cdot m]$$

$$M_2 = 7,82 \cdot 0,05 = 0,39 [kN \cdot m]$$

The durability limit for steel 45 σ_{-1}=257 MPa this steel is already choosed.

$$[\sigma] = \frac{\sigma_{-1}}{k_0 [S]}.$$

k_0 –coefficient for the detail construction, for the axis = 2,0…2.8, we take k_0 – 2.5. [S] – allowable safety factor, for M2 mechanisms classification group [S]=1,4;

$$[\sigma] = \frac{257}{2,5 \cdot 1,4} = 73,4 \text{ MPa}$$

Most dangerous part of drum under right section is axis, and calculated as follows:

$$d \geq \sqrt[3]{\frac{M}{0,1[\sigma]}} .$$

$$d \geq \sqrt[3]{\frac{0,39 \cdot 10^6}{0,1 \cdot 73,4}} = 37,5 \text{ [mm]}$$

To be consistent with [24] - diameter of bearings equal 40 mm. It’s the №1308 bearings with the statical capacity of cargo 8.8 kN.

Radial loading for the bearing R_B=7,82 kN<C_0=8,8 kN, so we achieve the required statical strength.

3.5 Braking device calculation

We calculated braking moment as follows:

$$T_{b.m} \geq T_{b.r} = K_b T_{st} \ .$$

K_{st} – safety braking coeffient, for M2 group mechanism classification is K_{st}=1,5;

T_{st} – cargo static torque moment.

$$T_{st} = \frac{GD\eta}{2u_{mech}} \ .$$

η – efficiency of mechanism, =0,85;

u_{mech} – rate of gear reduction, u_{mech} = 16. (including block/tuckle).

$$T_{st} = \frac{50 \cdot 0{,}1610{,}85}{2 \cdot 16} = 0{,}21 \ [\text{kN} \cdot \text{m}]$$

$$T_{b.r.} = K_b T_{st} = 0.315 \, [\text{kN} \cdot \text{m}]$$

The required brakes should have nominal braking moment bigger than 0.315kNm.

3.6 Parameters of electric engine

The maximum required statical power for lifting of cargo was found thorugh the following formula:

$$P_{st\max} \approx \frac{Gv}{\eta}$$

η =0,85 – approxinatelly mechanism efficiency.

$$P_{st\max} = \frac{50 \cdot 20}{60 \cdot 0,85} = 19,6\ [\text{kW}]$$

The necessary power was found as follows:

$$P_{ep}\text{=}0{,}75P_{stmax} = P_{ep}\text{=}0{,}75P_{stmax} = 14.7\ [\text{kW}]$$

In result, it’s required to take electric engine with more or equal power 15 kW. For example, we take engine with the following characteristics: P_{ep}=15 kW, frequency of rotation n_{ef} = 700 min^{-1}, fly wheel effect D^2=1,71 kgm^2

3.7. Calculation of gear box parameters

The necessary gear box ratio was calculated by the following formula:

$$u_{gbr} = \frac{n_{en}}{n_{dr}}\ .$$

n_{eng}, n_{dr} – frequency of rotation of drum and engine.

The frequency of rotation of the drum rotation was found by the formula:

$$n_d = \frac{vn_{bt}}{\pi D}$$

n_{bt} - mechanical advantage of the block/tackle; D – diameter of drum.

$$n_d = \frac{20 \cdot 4}{3{,}14 \cdot 0{,}16} = 159{,}2[\min^{-1}]$$

$$u_{gbr} = \frac{700}{159{,}2} = 4{,}39$$

To be consistent with [25] we choosed the speed reducer.

Highest statical moment of drums shaft of lifting mechanism was found as follows:

$$T_{max} = \frac{F_{max} D Z_{n.r.}}{2\eta_d}$$

η_d = 0,98 it's drum efficiency.

$$T_{max} = \frac{6,9 \cdot 0,16 \cdot 2}{2 \cdot 0,98} = 1,13[kN \cdot m]$$

Equivalent moment on output shaft of speed reducer was found as shown:

$$T_{eqiv} = K_l T_{max}$$

K_l=0,5 is coefficient of lifetime.

$$T_{equiv} = 0,5 \cdot 1,13 = 0,565[kN \cdot m]$$

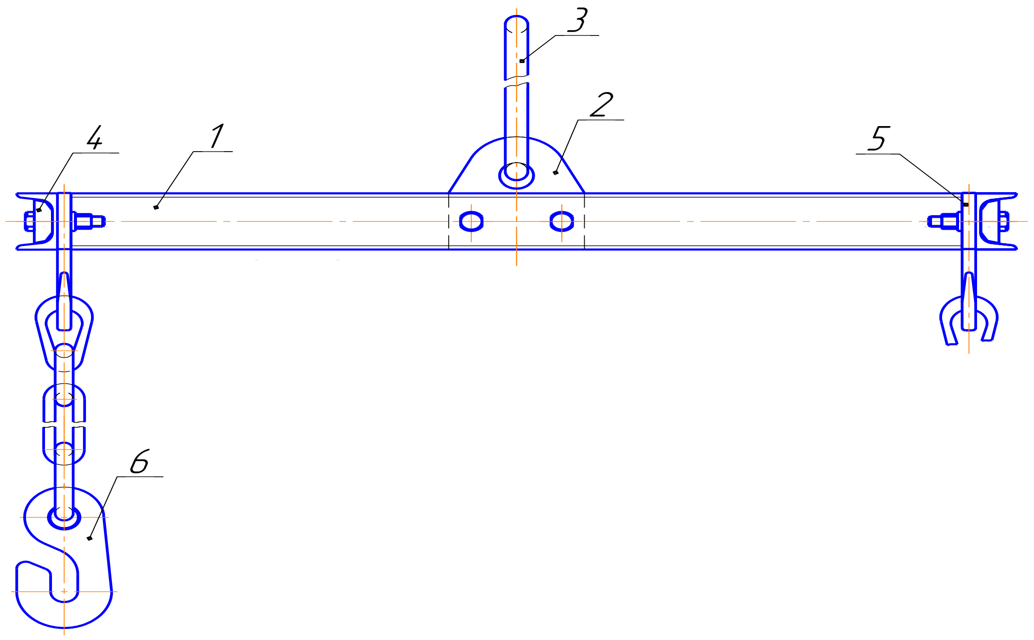
Fro our calculations it's assumed that we take speed reducer that designed in ЦУ-200 family, the reduction gear rate n_{rgr}=4, rotational moment T_r=2000 N*m.

Speed reducer parameters - correct, we can decide this through following relation: T_{equiv}=565 N*m<T_r=2000 [N·m].

3.8 Lifting traverse design

The lifting traverse contains a longitudinal beam with a special eye for engaging with a hook of the hoist mechanism, two cross beams with clamps, which are rigidly fixed in the central part of each of the cross beams.

Holes are made in the longitudinal beam for fixing the transverse beams with fixing pins. The retaining pin is provided with a vertically positioned pin designed to prevent spontaneous movement.



(1 - frame, 2 - lug, 3 - hinged ring, 4 - bar, 5 - hinged hook, 6 - suspended hook)

Figure 3.4 – General design of lifting traverse

The design being developed is a spatial H-shaped traverse with a central eye. This type of lifting traverse can be used to load standard type of loads such as pallets, containers, also this traverse can be used for loading of oversized or cargo with displaced centre of gravity. The main characteristics of the designed lifting traverse are shown in the table 3.

Table 3.6 Main characteristics of lifting traverse

Parameter	Value
Load capacity	2000 kg
Working width, maximum	910 mm
minimum	610 mm
Number of capture points	4
Dimensions:	
length	985 mm
width	812 mm
height	174 mm
Mass of traverse	40 kg

The lifting beam is a welded structure, the main part of which is the frame. The frame consists of two longitudinal and two transverse beams. The longitudinal beams are fastened together with a hole, the transverse ones, in turn, are welded to the ends of the longitudinal ones.

Also, to strengthen the structure at the junction of the beams from the top and bottom, a gusset plate is welded. The cross beams are equipped with removable hooks, four hooks on each beam, as a result of which the position of the hook can be changed, depending on the work performed. The traverse can be equipped with chains with hooks attached to them.

3.9 Strength analysis of the main elements of traverse

Calculation of the traverse.

To calculate the strength of the traverse, the following parameters were choosed:

1) material – Fe37-3FN;

2) U-section 6,5 DSTU (National Standard of Ukraine) 8768:2018;

3) cargo capacity – 4500 kg;

4) traverse mass – 40 kg;

Normal stress are initiated in section A-A.

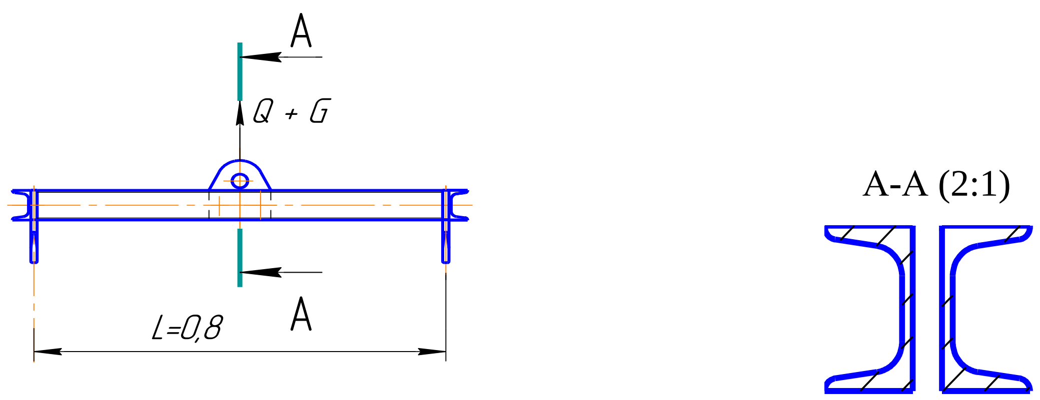


Figure 3.5 - Calculation of the bending moment in section A-A

The main stress is normal, which is determined by the following formula [26]:

$$\sigma = \frac{M_b}{W_X} \qquad 3.1$$

$W_X = 15$ cm^3 is the axial moment of resistance, but since the longitudinal beam consists of two sections, therefore the axial moment of resistance will be equal to 30см^3.

M_b – maximum bending moment.

Bending moment is determined by the formula 3.2.

$$M_b = \frac{Q \cdot L}{4} = \frac{20 \cdot 0{,}8}{4} = 4 \qquad 3.2$$

$$M_b = \frac{Q \cdot L}{4} = \frac{20 \cdot 0{,}8}{4} = 4$$

where Q is the carrying capacity of the traverse;

L - distance between hooks;

We substitute the obtained data into formula 3.1:

$$\sigma = \frac{M_b}{W_X} = \frac{4}{30 \cdot 10^{-6}} = 133333 \text{ [kN/m2]} = 133 \text{ [MPa]}.$$

Calculation of the transverse part of the traverse in section B-B.

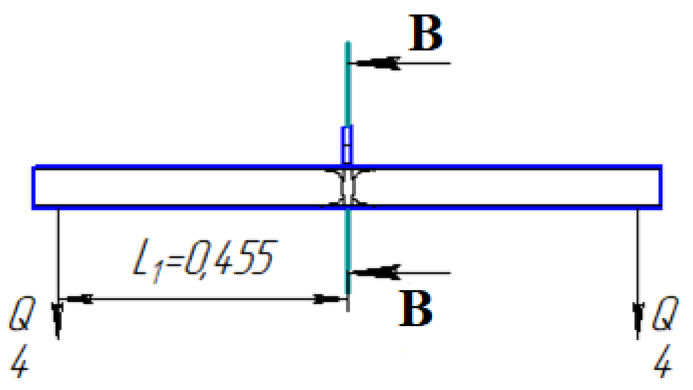


Figure 3.6 - Calculation of bending moment in cross section B-B

The main stress is normal, which is determined by the following formula [26]:

$$\sigma = \frac{M_b}{W_X}$$

$W_X = 15$ см^3 is the axial moment of resistance;

M_b – maximum bending moment.

Bending moment is determined by the formula [26]:

$$M_b = \frac{Q \cdot L}{4} = \frac{20 \cdot 0,455}{4} = 2,27$$

where Q is the carrying capacity of the traverse;

L - distance between hooks;

We substitute the obtained data into formula 3.1:

$$\sigma = \frac{M_b}{W_X} = \frac{2,27}{15 \cdot 10^{-6}} = 151333 = [kN/m2] = 151 [MPa].$$

3.9.1 Calculation of the hanging hook

Calculation of the hanging hook is provided be the following:

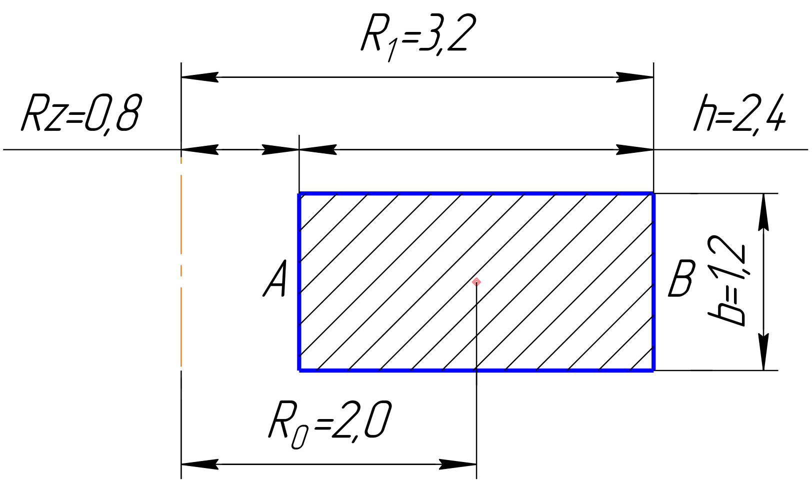


Figure 3.7 - Cross-section of a hanging hook

Firstly, it is necessary to calculate neutral laler radius of hook as follows:

$$r = \frac{h}{2,3 \cdot \lg \frac{R_1}{R_Z}},$$

where r – is the radius of the neutral layer;

h – section length;

R_1 – radius from the neutral line to the outer boundary of the section;

R_Z – radius from the neutral line to the inner border of the section;

We have:

$$r = \frac{2,4}{2,3 \cdot \lg \frac{3,2}{0,8}} = \frac{2,4}{2,3 \cdot 0,602} = 1,7329[cm];$$

Calculate the following parameters:

$$z_0 = R_0 - r = 2 - 1,7329 = 0,2671[cm];$$

$$S = F \cdot z_0 = 2,4 \cdot 1,2 \cdot 0,2671 = 0,7692[cm]$$

$$z_1 = \frac{h}{2} + z_0 = \frac{2,4}{2} + 0,2671 = 1,4671[cm]$$

$$z_2 = \frac{h}{2} - z_0 = \frac{2,4}{2} - 0,2671 = 0,9329[cm]$$

Where R_0 – is the radius from the neutral line to the center of the section;

F – cross section area.

Normal stress is defined thought the following formula:

$$\sigma_1 = \frac{N}{F} + \frac{M_b \cdot z_1}{S \cdot R_1},$$

The bending moment relative to the center of gravity of the section is $M_b = -300 \cdot 2 = -600 kg/cm$ =-6 kN/cm; normal force N=3 kN; cross-sectional area F=2.88 cm^2.

Normal stress in point A and point B is:

$$\sigma_1 = \frac{N}{F} + \frac{M_b \cdot z_1}{S \cdot R_1} = \frac{3}{2,88} + \frac{(-6) \cdot 1,4671}{0,7692 \cdot 3,2} = 1,0417 - 3,5762 = -2,54[kN/cm^2] = -25,4 \text{ [MPa]}.$$

$$\sigma_2 = \frac{N}{F} + \frac{M_b \cdot z_2}{S \cdot R_Z} = \frac{3}{2,88} + \frac{6 \cdot 0,9329}{0,7692 \cdot 0,8} = 1,0417 + 9,0961 = 10,14[kN/cm^2] = 101,4 \text{ [MPa]}.$$

3.9.2 Calculation of the suspension hook

Calculation of suspension hook is provided be the following:

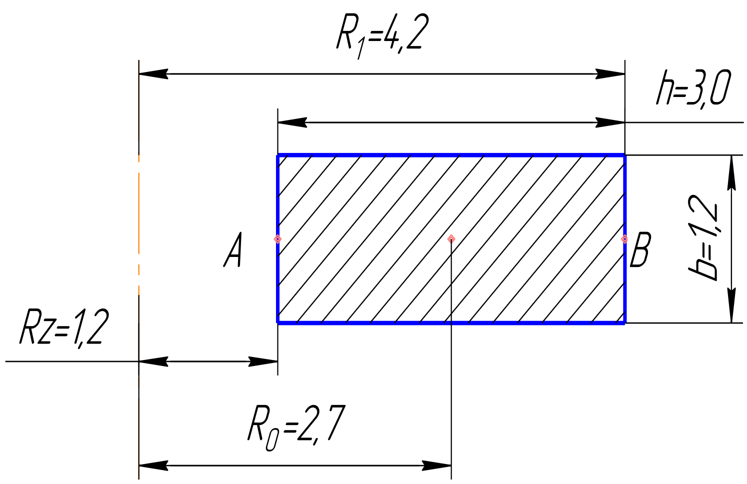


Figure 3.8 - Cross-section of the suspension hook

Firstly, it is necessary to calculate neutral laler radius of hook as follows:

$$r = \frac{h}{2,3 \cdot \lg \frac{R_1}{R_Z}} = \frac{2,4}{2,3 \cdot \lg \frac{4,2}{1,2}} = \frac{3}{2,3 \cdot 0,5411} = 2,4106[cm];$$

where $r-$ is the radius of the neutral layer;

$h-$ section length;

R_1- radius from the neutral line to the outer boundary of the section;

R_Z- radius from the neutral line to the inner border of the section;

Calculate the following parameters:

$$z_0 = R_0 - r = 2,7 - 2,4106 = 0,2894[\text{cm}];$$

$$S = F \cdot z_0 = 3 \cdot 1,2 \cdot 0,2894 = 1,0419 \ [\text{cm}^3];$$

$$z_1 = \frac{h}{2} + z_0 = \frac{3}{2} + 0,2894 = 1,7894 \ [\text{cm}];$$

$$z_2 = \frac{h}{2} - z_0 = \frac{3}{2} - 0,2671 = 1,2329 \ [\text{cm}];$$

Normal stress is defined thought the following formula:

$$\sigma_1 = \frac{N}{F} + \frac{M_b \cdot z_1}{S \cdot R_1},$$

The bending moment relative to the center of gravity of the section is $M_b = -300 \cdot 2,7 = -810 kgcm$ = -8,1 kN/cm; normal force N=3 kN; cross-sectional area F=3.6.

Normal stress in point A and point B is:

$$\sigma_1 = \frac{N}{F} + \frac{M_b \cdot z_1}{S \cdot R_1} = \frac{3}{3,6} + \frac{(-8,1) \cdot 1,7894}{1,0419 \cdot 4,2} = 0,83 - 3,3122 = -2,48 [kN / cm^2] = -24,8 \text{ [MPa]}.$$

$$\sigma_2 = \frac{N}{F} + \frac{M_b \cdot z_2}{S \cdot R_Z} = \frac{3}{3,6} + \frac{8,1 \cdot 1,2329}{1,0419 \cdot 1,2} = 0,83 + 7,987 = 8,82 [kN / cm^2] = 88,2 \text{ [MPa]}.$$

3.9.3 Calculation of axes of fastenings

Calculation of axes of fastening of longitudinal beams and eyelets for bending:

Determine normal stress during the bending:

$$\sigma = \frac{M}{2W},$$

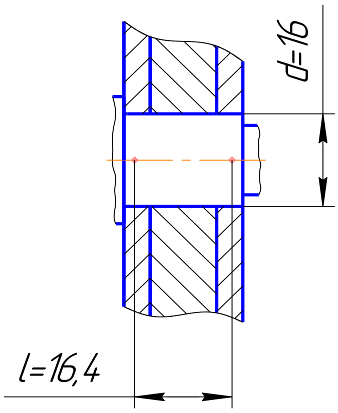


Figure 3.9 - Cross-section of the axle of fastening of the longitudinal beams and eyelugs.

where W – is the axial moment of strengh;

M – bending moment;

$$W = 0{,}1d^3 = 0{,}1 \cdot 0{,}016^3 = 0{,}41 \cdot 10^{-6} \, [\text{m}^3].$$

Bending moment was found as follows:

$$M = \frac{Q \cdot l}{4},$$

where Q – is the workload;

l – length of the loaded section;

So we have:

$$M = \frac{Q \cdot l}{4} = \frac{12 \cdot 0{,}0164}{4} = 0{,}0492 \; [\text{kN·m}];$$

$$\sigma = \frac{M}{2W} = \frac{0{,}0492}{2 \cdot 0{,}41 \cdot 10^{-6}} = 60000 \, \text{kN/м}^2 = 60 \; [\text{MPa}].$$

3.9.4 Calculation of eyelug

Calculation of the eyelug for tensile:

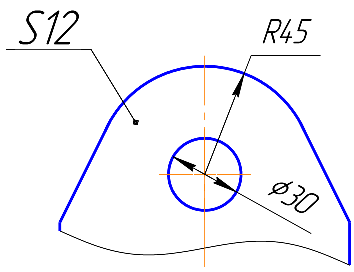


Figure 3.10 - Cross-section of the eyelug

Under central tension, a normal stress arises in the cross section, which is determined by the formula:

$$\sigma = \frac{N}{F},$$

where N – longitudinal force; $N = Q + G$;

Q – workload;

G – mass of traverse;

F – cross section area, where $F = (45 - 15) \cdot 12 = 360$[mm^2];

$$\sigma = \frac{Q+G}{F} = \frac{12+0{,}4}{360\cdot 10^{-6}} = 34444\ \text{кN/m}^2 = 34\ [\text{MPa}].$$

3.9.5 Calculation attachment axes of the hook

Calculation of the attachment axes of the hook for shear:

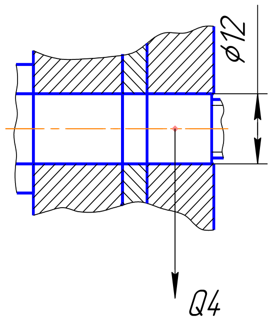


Figure 3.11 - Cross section of the hanging hook

The normal stress is found by the formula:

$$\sigma = \frac{Q/4}{F} \le [\sigma];$$

$[\sigma]_{shear} = 48$ МПа – allowable stress;

Q – working load;

F – cross section area;

$$F = \frac{\pi \cdot d^2}{4} = \frac{3{,}14\cdot 1{,}2^2}{4} = 1{,}13\ [\text{см}^2]$$

$$\sigma = \frac{2000/4}{1{,}13} = 442\ \text{kN/cm}^2 = 44{,}2\ [\text{MPa}].$$

The design stress equal to 44,2 MPa is less than the allowable 48 MPa, therefore, the strength condition is met.

The required breaking force of the chain is found by the formula:

$$P_P = \frac{Q}{4}\cdot k = \frac{2000}{4}\cdot 5 = 2500[kg];$$

Conclusion to the part

The main design parameters of the upper loading device and the attachment traverse have been calculated. The designed cargo capacity of the upper loading device is up to 5 tons. This upper loading device with traverse is attached for special rails under the ceiling. This device can lift the cargo for the 3.5 meters heught. The designed height satisfies our requirements, so this device can easely operate on the fuselage with diameter 3.35 meter. The speed of lisft is up to 20m/min and horizontal movement up to 25 m/min.

The upper loading device with attached traverse can move different types of cargo from the front part of cargo cabin to the rear part.

This upper cargo loading device is able to load and unload different ULDs, including pallets and containers. However, as to the topic of master thesis, the traverse is designed to load unbalanced cargo and different types of oversized caego.

The cargo will be attached for the upper loading device with the designed traverse. The cargo can be loaded and loaded without special additional fateners.

Designed mechanism is used to decrease the time of handling in airports and to speed up the process of cargo loading, those the airlines will save a lot of money, since the airplane will not stay on airport for a long period.

The designed traverse will attach the cargo that is located on the cargo ramp. To move the cargo from the ground to the cargo ramp special cargo loaded may be required.

For this issue it was chosed the model of the traverse that is perfectly solve the problem with unbalanced cargo.

The lifting traverse has a lot of advantages to compare the simple hook, that is used for lifting the cargo. Additionally, lifting traverse is a good variant not only for oversized cargo, but also it can be used for loading different types of ULDs observed in this part.

PART 4. ENVIRONMENTAL PROTECTION

4.1 ICAO requirements towards noise pollution

Airplane noise is the largest significant root of community reaction that relates to the airports operation. One of the main priorities of ICAO is to decrease the number of people that affected by significant airplane noise.

Airplane noise usually is the main environmental issue for people impacted by airplanes operations, whether this is from the major international airports, night-time flights, helicopters, and airfields with the repetitive activities like an aerobatic practice, or in the result of the changes of flightpath.

We can define noise as “unwanted sound.” Airplane noise is one of the most harmful environmental effect of aviation. This harmful effect may cause several problems in community life, such as: disrupt sleep, increase risk of cardiovascular disease of people that live near the airports. In several airports, noise limit an air traffic growth.

During the certification, each airplane must be certified for noise [28]. Noise created by aircraft is measured at three points:

• Take-off (6.5 km from roll start)

• Side-line on the runway (450 m from runway)

• Approach (2 km from the runway thresholdand and 120m high).

For each of the three points of measurement, the limits are agreed at ICAO level. Such limits depend on the airplane weight during take-off and number of the engines. The sum of differences at all three measurement points between maximum noise levels and Chapter 3 max. noise levels must not be less than 10 EPNdb and this is called “Cumulative Noise Margin”.

During the time noise limits have been agreed, taking into account noise reduction that is achieved for individual type of aircraft due to the technologies improvement over the time.

For jet airplanes for example, the limits are referred to the Chapter 2, Chapter 3, Chapter 4, and Chapter 14.

Depending on the year, the type certificate was agreed, and each airplane must obey the limit:

- Chapter 2: Type certificate submitted before 6th October 1977
- Chapter 3: Type certificate submitted before 1st January 2006
- Chapter 4: Type certificate submitted before 31st December 2017
- Chapter 14: Type certificate submitted on or after 31st December 2017

To be consistent with recommendations of "Special Meeting on Aircraft Noise in the Vicinity of Aerodromes" (1969), draft International Standards and Recommended Practices for Aircraft Noise were discussed and were applicable in 1972 [29]. That standards show 3 reference measurement points for aircraft noise certification, that are illustrated in figure 4.1. The standards are also set the noise limits as a direct function from Maximum Take-off Mass (MTOM) in order to identify that heavier aircraft, that were of bigger transport capability, create more noise pollution than light aircraft.

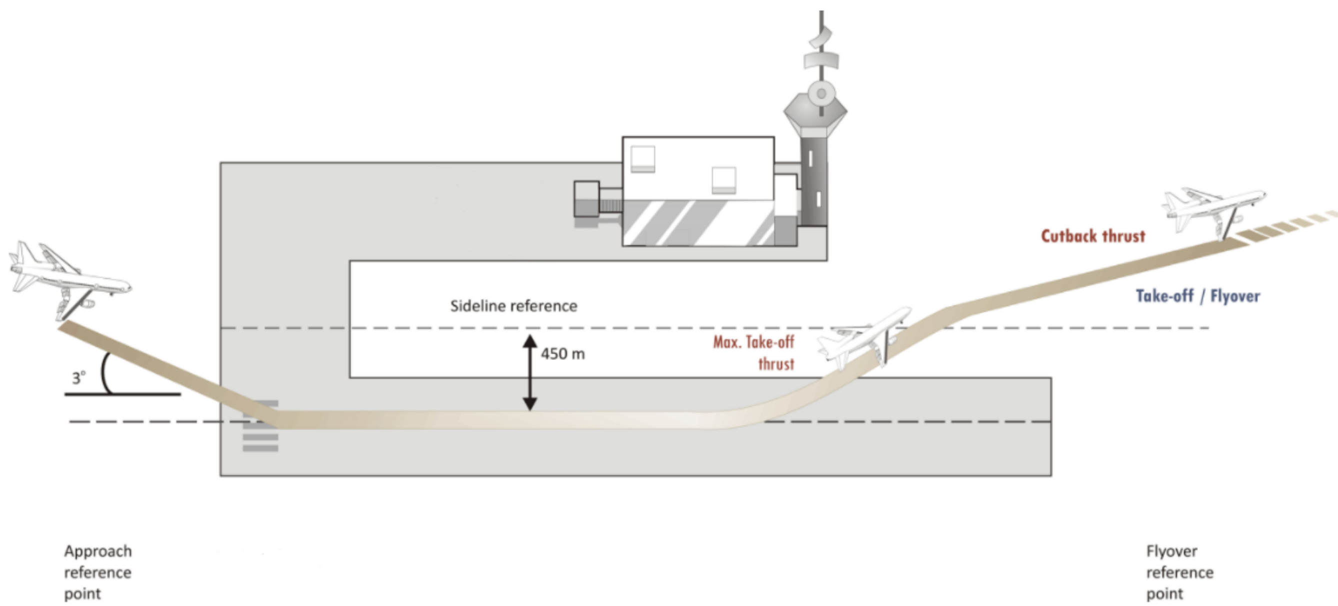


Figure 4.1 – Aircraft noise certification reference measurement points

In the following years, noise reduction technologies have been incorporated into airplane engines and airframe designs that led to improvements in aircraft noise performance and in result in further increase of the noise standard which is contained in Annex 16, Volume I, Chapter 4.

More stronger standard is shown in figure 4.2, and this standard will be the main to ICAO standards for subsonic jet airplanes and propeller-driven aircraft noise for the following years. This standard is applicable to new aircraft types submitted for certification on/or after 31 December of 2017, and on/or after 31 December 2020 for aircraft less than 55 tons in mass [30].

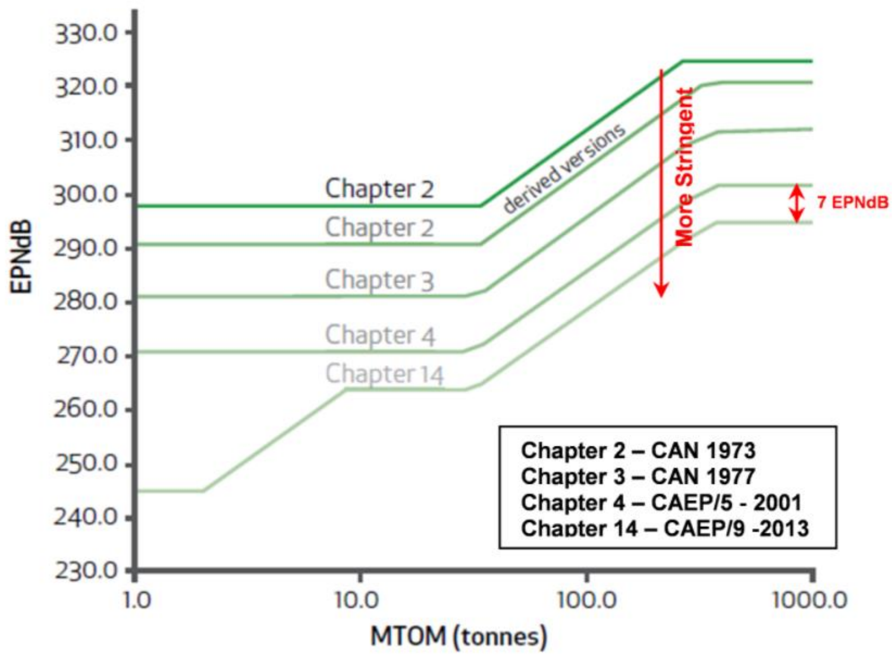


Figure 4.2 - The progression of the ICAO noise standards for airplanes

As a result of new Chapter 14 noise standards, it is assumed that number of people that are affected by aircraft noise will be reduced and more than one million persons could be removed from "Day Night average sound Level (DNL) of 55 dB affected areas" between the years 2020 and 2036.

Table 4.1 - Estimated long-term prospects for aircraft noise reduction by 2030

Aircraft category	Long term goals, EPNdb
Regional jet aircraft	
40 t (nominal)	21.5 ± 4
50 t (maximum)	17 ± 4
Twin-engine short / medium range aircraft	
Turbofan:	
78 t (nominal)	30 ± 4
98 t (maximum)	26.5 ± 4
With bi-turbo fan engines	
78 t (nominal)	13.5 + 2 / -6
98 t (maximum)	10.5 + 2 / -6
Twin-engine trunk aircraft	
230 t (nominal)	28 ± 4
290 t (maximum)	24.5 ± 4
Four-engine trunk aircraft	
440 t (nominal)	27 ± 4
550 t (maximum)	20.5 ± 4

4.2 Ways to delaminate noise pollution

Airplane noise may be disturbing to people who live near airports. For years, the industry working to reduce airplane noise, with significant progression: noise level has been decreased in the past ten years. This is assumed that noise influence of each new aircraft generation is lower at least 15% to compare with previous models.

Research for the noise reduction has been large to examine the following the amount of air that goes through the engines, size of the engine fan blades, the location of engine on airplane body and actually the number and size of wing flaps that help to change wing shape.

ICAO has adopted “Balanced Approach” concept to learn noise problems near airports and find different ways to fight with this issue. Noise problems that cause limitations of operation in the airport level and resistance to the designing of new airports or to the area growth of existing ones. For these causes, a common approach is required to avoid incoordinate policies that could guide to negative effects.

The main idea of balanced approach is to solve airplane noise problem at each airport in the most responsible, economically and environmentally way. The balanced approach idea corresponds to list of the principles which may help airports to decrease their ground noise impacts.

Figure 4.3 - Balanced approach pillars

1. Reducing of noise at each source (airplane): this is depending from noise certification standards.

2. Planning and management: this action is to checking the areas around airports according to the noise level and to allow only some activities inside these territories.

3. Noise decreasing operational procedures: this is to modify airplane operations to use specific runways, provide rest periods, etc. to reduce noise. This is the most effective measure.

4. Operating restrictions: This include phase-out of certain airplane type, use of the auxiliary power unit restriction. Such restrictions may also have an economic impact, so it is recommended to use them only when the other measures are not effective.

Other ways to reduce noise proposed by balanced approach are to use the noise monitoring systems. Every airport must check what are the main reasons of the noise problems and set noise objectives that should be achieved.

If there are some differences between objectives and evolution of noise problem, then the problem exists. The airports might have different issues regarding noise pollution, different ways to assess the issues and also different objectives.

ICAO also established the guidelines for assessing noise around airports, stating that good indicator is a number of people exposed in excess of a specified index. Very careful consideration should be given to reducing the number of people following the application of noise abatement measures, as it may happen that more flights (and more noise) focus on a minority of people.

The industry is hard working to make airplanes to near 50% quieter by the 2025. There is a strong incentive to continue to tackle this problem, as concerns of noise pollution may – and does – affect the speed of airport expansion plans.

To control where the airplanes fly during take off and landing has an huge influence on noise pollution. The location and use of the runways is basic, for example, airplanes that travel at night, they may flight over the seas or some lakes to decrease the noise impact.

An air traffic management should try make the such map of flight that to avoid the most populated areas. The navigation developments shows that airplane can follow designated route. Management of air traffic needs to undertake in close work with some community groups.

With the help of the air navigation services and airport operators, airlines and also pilots may implement noise reduction tasks, such as reduced thrust during take-off, continuous descent operations and displaced landing thresholds.

In addition, with aircraft noise decreasing, the land-use planning is main to minimize the number of people affected by airplane noise pollution. Airports have to work with regional authorities to make zoning rules for noise affected areas. Efficient land-use planning program should prevent of designing of new buildings for educational, living or health developments, and encourage building developments that are not affected to airplane noise, such as storage buildings and light industry. If we are talking about existing areas where houses are located, it may be useful to design additional insulation to decrease indoor noise level.

Unfortunately, in most cases airport operators have no control over land-use planning off the airport site and can only encourage local government to consider airport noise when approving plans for residential and other noise sensitive land use. The industry encourages governments to take a long-term proactive planning approach to land use around airports to ensure that no future development will be negatively impacted by excessive aircraft noise.

Conclusion to the part

The main sources of noise are aircraft and helicopter engines. Their noise impact extends not only to the airport and nearby areas, but is also noticeable along the entire flight route and is perceived by many people. Noise is also created by auxiliary power units of aircraft, special vehicles for various purposes, cars with thermal and wind turbines made on the basis of aircraft engines that have exhausted their flight life, equipment of stationary objects where maintenance and repair of aircraft are carried out. Noise levels at airport aprons reach - 100 dB.

Airplane noise can affect about a third of urban areas. At the same time, aircraft noise causes the greatest annoyance of grazing in comparison with other types of noise. The noise level of the aircraft is depending on the type of aircraft and mainly from type of engine that is installed on airplane. Many parameters noise pollution depend on the following flight parameters such as takeoff, landing, flight trajectory.

Technological improvement is providing to make airplanes less noisy, however increasing of air traffic indicates that more and more effort must be made to decrease noise level during airplane flight and around airports.

PART 5. LABOUR PROTECTION

5.1 Introduction

During the investigation the main purpose of master thesis, one workplace was used when conducting all required procedures during investigation. This workplace may be considered as typical office workplace. The workplace include typical office chair, table, and computer. As the subject of the work, a design engineer working in front of personal computer. So, typical office room accommodation layout working conditions will be discussed and analyzed.

5.2 Analysis of working conditions

Design engineer workplace is located in the office room, that is part of the building that include many office rooms. Each office room has one workplace.

The area of the room is 8.75 m^2, with the following geometrical characteristics 3.5 m (length) x 2 m (width) x 2.5 m (height). The volume of the room or airspace is 21,875 $м^3$. Such building parameters are accepted by the Ukraine state construction rules (ДБН В.2.2-28:2010) [31]. The office room should be proportional to the number of workplaces in this room. There are a lot of types of rooms, but technically all of them have same design. For example in office there are two main types of workplaces such as open space, with some partitions between each workplace, and separate rooms for individual places.

Design and layout of personal office room is shown on the figure 5.1.

The main elements of the office room are: 1- system unit of computer, 2 - computer monitor, 3 – keyboard, 4 – table, 5 – chair, 6 – window, 7 – printer, 8 – door, 9 – fire extinguisher. In addition to the main elements of workplace for the design engineer, the room provides a special wardrobe for storing paper and other consumables. The office room has natural and artificial lighting. The window in the room is equipped with adjustable horizontal blinds, which protects the computer devices from direct sunlight. Office room walls are painted in the green. In is proved that green color has positive influence on people eyes. The surface of the floor in the room is covered with beige linoleum, which is very convenient for wet cleaning.

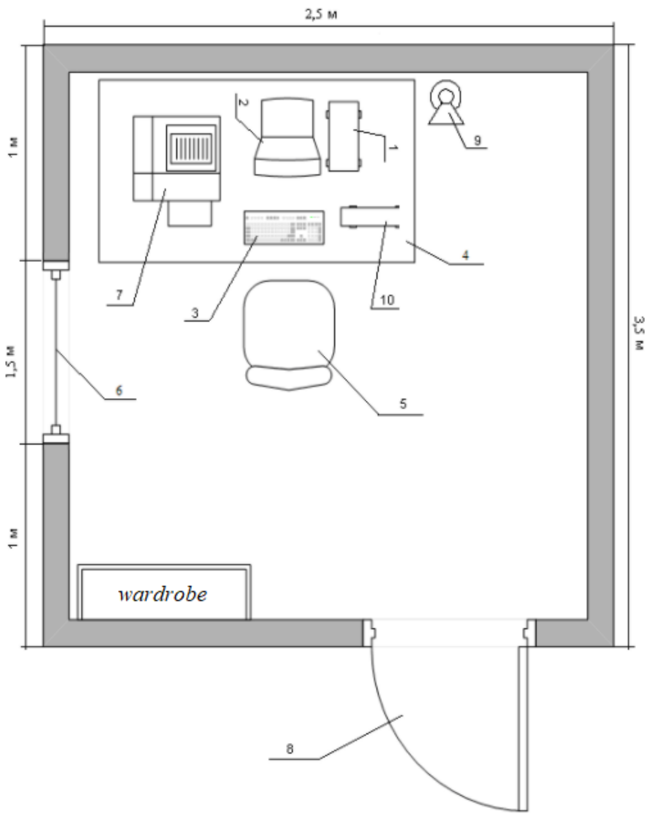


Figure 5.1 – Layout of the room workplace

A comfort leather chair allows you to adjust the height of the seat, the angle of the back of the chair, and the angle of the seat of the chair. The minimum height of the chair above the floor level is 400 mm, and the maximum – 500 mm, in addition, the chair leg is equipped with casters. The computer table provides convenient placement of controls, monitor and system unit. The table for the monitor has a height of 750 mm, the size of the table is 1400x900 mm. Also, the table has a special space for legs with following dimensions 700x680x700 mm. There is a footrest device under the table with dimensions 290x240x180 mm.

Figure 5.2 shows the personal workplace in accordance to Order of the State Committee of Ukraine for Industrial Safety “On Approval of the Rules of Occupational Safety during Operation of Electronic Computing Machines” of 26.03.2010 No. 65 [32].

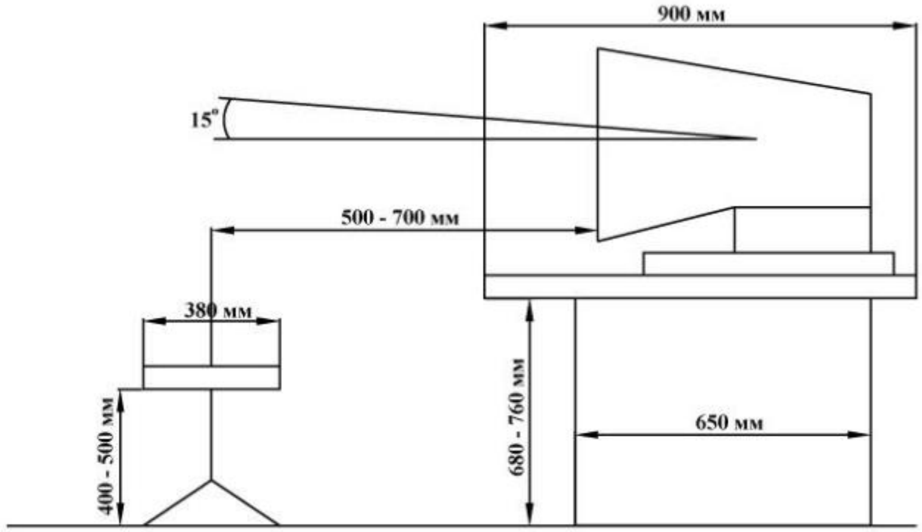


Figure 5.2 – Layout of personal workplace

Computer keyboard is located 160 mm from the edge of the table. Required distance between engineer eyes and computer monitor is approximately 650 mm. Computer monitor provides comfort observation at an angle of 15 °. Room temperature usually in range 24-26 °C in warm periods, and 19-23°C in cold periods, relative humidity in room usually 40-60%. The main source of noise pollution in room is noise from computer and printer. Also, there is a carbon fire extinguisher in the corner of the room to fight with fire, if it will be. The first aid kit is located on reception of office building.

5.3 Analysis of dangerous and harmful production factors

Harmful and dangerous factors are: low level of natural light; increased level of electric shock; increased level of noise in working area; increased ionizing radiation in workplace.

To provide the lighting on the office room, there are fluorescent lamps installed, in the office room. One window that measures 2 m x 1.5 m providing natural light. The window has two-layer glass and a plastic frame. The daylight factor is approximately 1.6%. Actual value of light is 215-250 lux.

Artificial lighting must provide illumination of working place with 300-500 lux. Artificial light seriously affects to the engineer vision. If there is not enough lighting, additional tidiness and stress may occur. Only artificial light can be improved normally:

Improving lighting in the working area requires to the reconstruct installed artificial lighting. One of the way may be to use different types of lamps, with changes of their quantity and power. For our working area it was chosen the LED lamps. LED lamps can convert electrical current directly into light, without losses of energy. LED lamps can emit narrow spectrum and do not heats, so the UV and the IR radiation is absent. In addition, LED lamps are devices that use low voltage, in result lamps are more safe.

There are no explosive mixtures in the workplace of the design engineer. Therefore, the electrical equipment for this room was selected in a general industrial design with a degree of protection of enclosures IP-20, where: IP - International Protection;

2 - protection against ingress of solid foreign bodies with a diameter of ≥ 12.5 mm; 0 - no protection against water ingress. The uninterrupted operation of any electrical equipment depends on the stability of the parameters of the industrial network. The stability of the network parameters is expressed in network noises, the main of which are high-voltage impulse voltage surges (up to 3 kV), periodic voltage surges of lower amplitude, long-term voltage drops to 150-170V, periodic voltage drops when connecting powerful equipment, frequency instability, short-term interruptions supply voltage, etc. All these interferences affect the performance of the computer and can lead to data loss, overheating, freezing, and even complete failure. The only protection of a computer and other equipment from network noise is an uninterruptible power supply - UPS (Uninterruptible Power Supply - UPS). According to the classification of premises according to the degree of danger of electric shock to people, the considered room with a computer belongs to premises without increased danger of electric shock, because there is a small amount of grounded equipment in the room, relative humidity <75%, average daily room temperature about + 24C, working voltage 220 V.

The level of acoustic noise has a great influence on the activity of the design engineer who is working with computer. Strong noise causes difficulties in recognizing color signals, reduces the speed of color perception, visual acuity, visual adaptation, disrupts the perception of visual information, and reduces labor productivity by 5-12%.

Most modern computers operate almost silently. Noise reduction is ensured by the use of elastic spacers between the base of the machine, the device and the supporting surface. A working system unit of a computer, a printer and other office equipment can serve as a source of noise in a room. Vibration is understood as mechanical, often sinusoidal, vibrations of a system with elastic links that arise in machines and apparatus with a periodic displacement of the center of gravity of a body from the equilibrium position, as well as with a periodic change in the shape of the body, which it had in a static state.

Vibrations do not play a significant role in the operation of a computer. The source of vibration can be a computer, printer and other office equipment, so they must be supplied with rubber pads on which they can be installed.

In accordance with the requirements in [33], when performing the main work on the computer, the noise level at the workplace should not exceed 50 dBA. In the room, the noise level does not exceed 30 dBA, which meets the requirements of the regulatory document.

5.4 Development of labor protection measures improvements

Collective and individual protection means are used to reduce the impact on workers of harmful and dangerous production factors. Collective protective ides is used to prevent, and decrease the impact of these factors:

- dust of some substances, that may lead to problems with respiratory system of person, problems with nervous system, loss of consciousness. To avoid such effects it is necessary to normalize the air flow in the working area, with the help of ventilation and air conditioning;

- insufficient lighting in the working area may lead to problems with visual understanding and injury. To avoid such problems it is required to normalize the lighting level in workplace by increasing of light sources, light filters, lighting protective equipment;

- electrical shock which may lead to injury or death. To avoid the impact of electrical shock on person following protective equipment may be used: automatic shutdown of electric circuit, grounding, some closures;

- increased temperatures of working equipment may lead to leading to body burns or overheating. To eliminate such conditions the workplace must be equipped with equipment ventilation, thermal insulation, air conditioners.

5.5 Fire safety

The most widespread as primary fire extinguishing means are various fire extinguishers, which are divided into manual, mobile (mounted on wheels and moved manually) and stationary (equipped with flexible hoses and hand barrels). Fire extinguishers, according to the type of fire extinguishing agent used, are divided into water, air-foam, powder, gas carbon dioxide and freon.

In out case, freon fire extinguishers are most often used to extinguish fires of electrical equipment under voltage, since freons have good dielectric properties. Freon (OH) fire extinguisher is a fire extinguisher with a charge of a fire extinguishing agent based on halogenated hydrocarbons. Freons such as the low-combustible gas Bromotrifluoromethane (CF3Br) or Freon 13B1, 12V1 (CF2ClBr), 114B2 (C2F4Br2) have found wide application for fire extinguishing.

For our working room it is enough to use two freon fire extinguishers, for example, with a capacity of 2 and 3 liters.

The fire alarm system is designed to detect the initial stage of a fire, transmit a notification about the place and time of its occurrence and, if necessary, turn on automatic fire extinguishing and smoke removal systems. The most important element of alarm systems are sensors - fire detectors, which, depending on the manifestations of the combustion process, can be heat, light and smoke.

Fire safety equipment is installed according to НАПБ А.01.001–2004 of Ukraine fire safety rules. СПД-3 is provided as the fire sensor alarm. This sensor alarm was designed to track the smoke in the 20m^3. For our room it is enough to install tree alarm sensors that are located on the ceiling. Figure 4.3 shows marked evacuation ways and emergency exits locations.

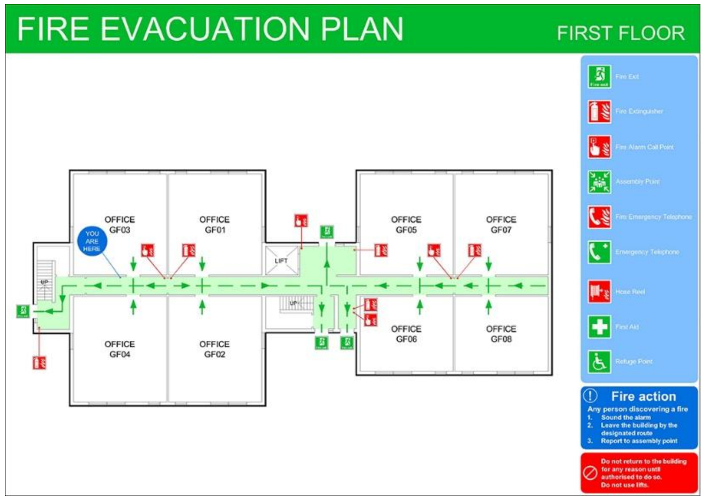


Figure 4.3 – Evacuation plan

5.6 Calculation of artificial lighting parameter

Normal illumination in room ($E_{\min}$) depends on visual work level that is performed in working room. The lowest illumination in room that is provided by ДБН В.2.5–28–2018 [34] equals at least 400 lux (lx). The real light value is approximately 200 – 250 lx. The total light is calculated as follows:

$$E_{gen} = \frac{E_n \cdot S \cdot k_1 \cdot k_2}{V}$$

where E_n – normal light illumination (E_n = 400 lx);

S – workplace area;

k_1 – aging lamps coefficient and lighting pollution (k_1=1.2);

k_2 – uneven illumination space coefficient (k_2= 1.1);

V – luminous flux ratio, depends on the walls reflection coefficient, geometryof room geometry and lamp types.

Room size: A = 2.5 m, B = 3.5 m, H = 2.5 m.

$S = A \cdot B = 2.5 \cdot 3.5 = 8.75$ m^2

Light flux ratio:

1. Coefficient of reflection of white ceiling ($R_{ceiling}$ = 70%);
2. Refraction index of green walls (R_{wall} = 50%);
3. Coefficient of reflection for floor (R_{floor}= 10%);
4. Space index ($i = \frac{A \cdot B}{h_p \cdot (A+B)}$).

$$h_p = H - h_n$$

where h_n– height of work surface under floor (h_n = 0.7 m).

Room rate calculated as follows:

h_p = 2.5 – 0.7 = 1.8 m

Light flux utilization is:

$$i = \frac{2.5 \cdot 3.5}{1.8 \cdot (2.5+3.5)} \approx 0.81$$

The total luminous flux is calculated as follows: (V=0.7)

$$E_{gen} \frac{400 \cdot 8.75 \cdot 1.2 \cdot 1.1}{0.7} = 6600\ lm$$

To provide total value of artificial lighting, it was selected LED lamps LED–T8SE–180. The flux luminous of each LED-T8SE-180 lamp is 20W, so, E_l=1650 lm.

To calculate the number of lamps that require to provide illumination in room:

$$N = \frac{E_{gen}}{E_l} = \frac{6600}{1650} = 4\ lamps$$

In result, to provide required light E_{gen} = 6600 lm output we need 4 lamps.

Conclusion to the part

In the Labour Protection chapter, the working conditions of a design engineer were analyzed. From the above discussions, it follows that a lot of unfavorable factors affect the work of a design engineer.

However, the harmful factors are eliminated or significantly reduced when the working conditions are consistent with regulatory requirements, with the correct organization of the workplace.

Based on the studied literature and regulatory documents, calculations required illumination in working place was performed, and the following measures were developed and proposed for implementation at the design engineer workplace to ensure comfortable working conditions.

REFERENCES

1. https://ifa-forwarding.net/blog/air-freight-in-europe/types-of-aircraft-shipping-cargo-and-types-of-loads/

2. Bischoff, E. and M. Ratcliff (1995). Issues in the development of approaches to container loading. Omega 23 (4), p. 377 – 390.

3. Brosh, I. (1981). Optimal cargo allocation on board a plane: a sequential linear programming approach. European Journal of Operational Research 8 (1), p. 40 – 46.

4. Chan, F. T., R. Bhagwat, N. Kumar, M. Tiwari and P. Lam (2006). Development of a decision support system for air-cargo pallets loading problem: A case study. Expert Systems with Applications 31 (3), p. 472 – 485.

5. Crabtree, T., T. Hoang, R. Tom and G. Gildemann (2016). Boeing World Air Cargo Forecast 2016-2017. Technical report, Boeing Commercial Airplanes. Available online from: www.boeing.com.

6. Конструкція та міцність літальних апаратів (частина 1): методичні рекомендації до виконання курсового проекту для студентівспеціальності 134 «Авіаційна та ракетно-космічнатехніка» /уклад.: С.Р. Ігнатович, М.В. Карускевич, Т.П. Маслак, С.В. Хижняк, С.С. Юцкевич. – К.: НАУ, 2018. – 91с.

7. Конструкція та міцність літальних апаратів (частина 2): методичні рекомендації до виконання курсового проекту для студентів спеціальності 134 «Авіаційна та ракетно-космічнатехніка» /уклад.: С.Р Ігнатович, Т.П. Маслак, С.В. Хижняк, С.С. Юцкевич. – К.: НАУ, 2018. – 48 с.

8. Karuskevich M.V., Zakiev V.I. Aviation and space rocket technology // Master degree thesis method guide. – K.: NAU, 2021. – 32 p.

9. Pilot's Handbook of Aeronautical Knowledge FAA-H-8083-25A - U.S. Department of Transportation. Federal Aviation Administration, 2008, 470 p.

10. Зайцев В.Н., Рудаков В.Л. Конструкция и прочность самолетов. -К.: Вища школа, 1978. – 213 с.

11. Конструкция и прочность воздушных судов: Учебное пособие / Ж.С. Черненко, Н.Г. Сабитов, В.В. Гаража и др. – К.: КИИГА, 1985. – 115 с.

12. Гаража В.В. Конструкция самолетов: Учебник. – К.: КМУГА, 1998. – 301 с.

13. Положення про дипломні роботи (проєкти) випускників Національного авіаційного університету, затверджене наказом ректора від 03.11.2006, №178/од.-К.: НАУ, 2011.-72 с.

14. Raymer, D., Aircraft Design: A Conceptual Approach, AIAA Press, 1989.

15. Federal Aviation Regulation, PART 25. Airworthiness standards. Transport Category airplanes. FAA, Department of Transportation. USA, 2004. – 220 p.

16. Авиационные правила. Ч. 25. Нормы летной годности самолетов транспортной категории. - М.; МАК. 1993. – 198 с.

17. Степыгин В.И., Чертов Е.Д., Елфимов С.А. Проектирование подъемно-транспортных установок. М.: Машиностроение, 2005. – 288 с.

18. Вайнсон А.А. Подъемно-транспортные машины. М.: Машиностроение, 1989. – 536 с.

19. Изместьева О.А., Кузнецов Б.С., Подъемно-транспортные машины. Темиртау, 2002. – 88 с.

20. GOST 25835-83 Lifting capacity cranes. Duty classifications of mechanisms.

21. GOST 2688-80 Two lay rope type. Dimensions.

22. GOST 6627-74 Single hooks. Blanks. Types. Construction and dimensions.

23. GOST 7872-89 Single and double direction thrust ball bearings.

24. GOST 33710-2015 Cranes. Selection of wire ropes, drums and sheaves.

25. GOST 28428-90 Double-row spherical ball radial bearings. Specifications.

26. GOST P 50891-96 Machine reducers. General specifications.

27. Сопротивление материалов: Учебное пособие. – 2-е изд., испр./ Н.А. Костенко, С.В. Балясникова, Ю.Э. Волошановская и другие; Под редакцией Н.А. Костенко. – М.: Высшая школа, 2004. – 430 с.: ил.

28. https://www.europarl.europa.eu/RegData/etudes/STUD/2020/650787/IPOL_STU(2020)650787_EN.pdf

29. https://www.hlnug.de/fileadmin/dokumente/laerm/gesetze/flugverkehr/ICAO_Annex16_Volume1.pdf

30. https://www.icao.int/Meetings/EnvironmentalWorkshops/Documents/NoiseCertificationWorkshop-2004/BIP_2_1AD.pdf

31. http://kbu.org.ua/assets/app/documents/dbn2/73.1.%20ДБН%20В.2.228~2010.%20Будинки%20і%20споруди.%20Будинки%20адмі.pdf

32. https://zakon.rada.gov.ua/laws/show/z0293-10#Text

33. http://zakon2.rada.gov.ua/rada/show/va037282-99. – (Державні санітарні норми)

34. https://ledeffect.com.ua/images/__branding/dbn2018.pdf

GENERAL CONCLUSIONS

The master degree thesis consists of the following main parts: the first part concentrates on the cargo that is delivered by airplanes. The first part introduces main management tasks that should be solved during the cargo load planing. Cargo load planning explains all steps that should be done to load different types of cargo on board such as pallets, containers, and different types of oversized cargo. The main idea of the first part is to develope effective method to load and unload of non-standard and unique large-sized on aircraft with the helpd of special devices like traverse.

The second part of master thesis is devoted to make the preliminary design of short range high wing airplane with cargo capacity up to 16 tons that will be used as a prototype for the installation of loading traverse which will provide loading and unloading cargo on aircraft.

In the third part of the thesis, it was designed a winch hoist with cargo capacity up to 5 tons and the loading traverse that is installed with whinch hoist. This upper loading assembly have a maxim heigt of lift near 3.5 meters. The winch hoist with traverse is mounted on the rails under the airplane fuselage ceiling. Such loading assembly gives a possibility to move different types cargo two directions: vertical and horizontal. The cargo capacity of designed H-type traverse is 4.5 tons that is enough to solve all cargo load management tasks when loading the oversized cargo on the short range airplane with maximum fuselage width 3.5 meters. The traverse is a part of all upper loading mechanism and since there are many types of traverses that have their own task, the traverse can be replaced by onether one to provide most effective load characteristcs.

The fourth part was devoted to the envirinmental protection. In this part it was discussed the influence of airplane noise and how to protect with it.

The fifth part was devoted to the labour protection where it was discussed and calculated main parameters of the engineers worplace and main factors that may influence on the efficiency of work.

The presented results of the master thesis with the design of specific upper loading device with installed traverse could improve the time of handling in airports and to speed up the process of cargo loading, those the airlines will save a lot of money, since the airplane will not stay on airport for a long period. Mainly, this type of cargo loading device will be usefull for loading and delivering oversized or non-standard cargo. Also, such device will provide high efficiency cargo loading of cargo including standard ULD cargo such as pallets and containers.