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: «Концепція та обґрунтування конструкції кулькової підлоги вантажної кабіни літака»

Виконавець: __________ **Ростислав АРТЮХ**

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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: "Concept and engineering background of the ball mat for aircraft cargo compartment"

Fulfilled by:	___________	**Rostyslav ARTIUKH**
Supervisor: **Dr. of Sc., professor**	___________	**Mykhailo KARUSKEVICH**
Labor protection advisor: **PhD, associate professor**	____________	**Victoria KOVALENKO**
Environmental protection adviser: **PhD, associate 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.
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«_____» ____________ 2021 р.

ЗАВДАННЯ

на виконання дипломної роботи студента

АРТЮХА РОСТИСЛАВА ВІТАЛІЙОВИЧА

1. Тема роботи: «Концепція та обґрунтування конструкції кулькової підлоги вантажної кабіни літака», 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 7500 кг, дальність польоту з максимальним комерційним навантаженням 1000 км, крейсерська швидкість польоту 570 км/год, висота польоту 9 км, габаритні розміри вантажної кабіни.

4. Зміст пояснювальної записки: аналіз кулькової підлоги у вантажній кабіні літака, аналіз ефективних методів завантаження та перевезення вантажу літаками короткого взльоту та посадки, проектування кулькового механізму передачі та обґрунтування конструкції кулькової підлоги вантажної кабіни літака.

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

6. Календарний план-графік:

№	Завдання	Термін виконання	Відмітка про виконання
1	Аналіз стану проблеми допоміжних механізмів у вантажній кабіні літака.	11.10.2021–12.10.2021	
2	Розробка методології розрахунку навантажень на кулькову підлогу та механізм передачі.	13.10.2021–20.10.2021	
3	Проведення досліджень та оцінка габаритів вантажу для заванантаження в літак. Проведення розрахунків.	21.10.2021–26.10.2021	
4	Розробка кулькового механізму передачі.	27.10.2021–16.11.2021	
5	Виконання задач розділу «Охорона праці» та «Охорона навколишнього середовища».	17.11.2021–22.11.2021	
6	Підготовка ілюстративного матеріалу, написання пояснювальної записки.	23.11.2021–28.11.2021	
7	Редагування, підготовка презентації та виправлення пояснювальної записки.	29.11.2021–31.12.2021	

7. Консультанти з окремих розділів:

Розділ	Консультант	Дата, підпис	
		Завдання видав	Завдання прийняв
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Охорона навколишнього середовища	к.т.н, доцент Тамара ДУДАР		

8. Дата видачі завдання: 8 жовтня 2021 року

Керівник дипломної роботи ____________ Михайло КАРУСКЕВИЧ

Завдання прийняв до виконання ____________ Ростислав АРТЮХ

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

Rostyslav ARTIUKH

1. Topic: «Concept and engineering background of the ball mat for aircraft cargo compartment», 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 7.5 tons, flight range with maximum capacity 1000 km, cruise speed 570 km/h, flight altitude 9 km, cargo cabin dimensions.
4. Content: analysis of the ball mat floor in the cargo cabin of the aircraft, analysis of effective methods of loading and transportation of cargo by short takeoff and landing aircraft, design of the ball transfer unit and engineering background of the ball mat for aircraft cargo compartment".
5. Required material: drawings of the general view of the cargo aircraft, design of the ball transfer unit mechanism.

6. Thesis schedule:

№	Task	Time limits	Done
1	Analysis of the state of the problem of auxiliary mechanisms in the cargo cabin of the aircraft.	11.10.2021–12.10.2021	
2	Development of a methodology for calculating the load on the ball floor and the transmission mechanism.	13.10.2021–20.10.2021	
3	Carrying out research and estimating the dimensions of cargo for loading into the aircraft. Carrying out calculations.	21.10.2021–26.10.2021	
4	Development of a ball transfer unit mechanism.	27.10.2021–16.11.2021	
5	Execution of tasks of the section "Labor protection" and "Environmental protection".	17.11.2021–22.11.2021	
6	Preparation of illustrative material, writing the report.	23.11.2021–28.11.2021	
7	Editing, preparing a presentation and correcting the report.	29.11.2021–31.12.2021	

7. Special chapter advisers:

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

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

Supervisor: ____________ Mykhailo KARUSKEVICH

Student: ____________ Rostyslav ARTIUKH

РЕФЕРАТ

Пояснювальна записка дипломної роботи магістра «Концепція та обґрунтування конструкції кулькової підлоги вантажної кабіни літака»:

83 с., 30 рис., 13 табл., 45 джерел

Дана дипломна робота присвячена розробці аванпроекту вантажного літака короткого взльоту та посадки для ближньомагістральних авіаліній та розробці кулькової підлоги вантажної кабіни, використовуючи концепцію кулькового механізму передачі.

В роботі було використано методи аналітичного розрахунку, компьютерного проєктування за допомогою CAD/CAM/CAE систем, зокрема CATIA, AutoCAD.

Практичне значення результату дипломної роботи магістра полягає в покращенні умов для завантаження та розвантаження вантажу, що сприяє більш швидкому процесу перевезення вантажів в цілому.

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

Дипломна робота, аванпроєкт літака, компонування, центрування, кульковий механізм передачі, розрахунок навантження

ABSTRACT

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

83 pages, 30 figures, 13 tables, 19 references

This master thesis is devoted to the development of a preliminary design of a cargo plane for short takeoff and landing for the development of the ball floor of the cargo cabin, using the concept of the ball transfer unit mechanism.

The design methodology is based on prototype analysis to select the most advanced technical decisions, engineering calculations to get the technical data of designed aircraft and computer based design using CAD/CAM/CAE systems, in particular CATIA, AutoCAD.

The practical significance of the result of the master's thesis is to improve the conditions for loading and unloading of goods, which contributes to a faster process of transportation of goods in general.

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, ball transfer unit, load calculation

Content

INTRODUCTION

The aviation industry provides us with the ability to quickly transport cargo from point A to point B, this type of transportation is considered fast and reliable.

The transportation of cargo in the shortest possible time has always been important in the aviation industry. Especially now in a pandemic, fast delivery of self-defense equipment, vaccines, etc. It is important to understand that the speed of cargo delivery is also influenced by the speed of unloading and loading into the cargo compartment of the aircraft.

Nowadays, there are many assistive devices, gadgets, which help to simplify and facilitate the loading of the plane. However, many of them are outdated and no longer effective compared to current progress.

Thus, there is the problem of the weight of the cargo aircraft cockpit ancillaries. One of the options for solving this problem is to consider changes in the structure of the floor of the cargo compartment of the aircraft in tandem with a classic winch. This will increase the speed of unloading and loading aircraft cargo and practically will not increase the weight of the aircraft in comparison with the crane.

This diploma work examines the use of a ball floor in the cargo compartment of a short takeoff and landing aircraft, as well as an analysis of the Ball Transfer Units (BTU) loads to ensure the fastest loading and unloading of the aircraft cargo compartment.

The main aim of this diploma work is to propose advanced ball mat for aircraft cargo compartment. To gain this aim the following objectives will be achieved:

- To derive ball mat design with account of aircraft capacity, expected loads on the floor, cargo compartment geometry and aircraft carcass structural design.
- To define maximum allowed commercial load on ball mat floor.
- To provide the strength of the ball mat by adequate calculation and selection of the constructional materials.

While working on mentioned tasks the materials of courses “Aircraft Design and Strength”, “Strength of Materials”, “Theory of Machines and Mechanisms”, etc. have been used.

The work meets requirements of “Certification Specification for Large Aircraft”, documents of Federal Aviation Administration, handbooks on Aircraft design, copybooks on the course “Equipment for Aircraft Cargo Holds and Containers Compartment”, guides for the Master’s degree thesis.

The work comprise also Chapters devoted to the problems of Labor protection and Environment protection.

PART 1. STATEMENT OF THE PROBLEM

1.1 Cargo loading process

The object of transportation must be delivered to the airport in advance, that is, with a reference to the timing of acceptance of the batch, pre-flight formalities, customs clearance, quarantine or veterinary control. To clarify the details, be sure to contact the carrier. Upon arrival of the cargo at the airport, the algorithm of actions is as follows:

- Weighing and measurement of cargo. Operations are carried out by authorized persons and only in the presence of the consignor. The weight of the cargo, which provides for several places in the aircraft, is determined in total with partial weighing.
- Checking the shipped batch for compliance with all necessary technical and legal requirements. The shipper's documents must contain only reliable information.
- Registration of documentation and provision of payment for the services of the carrier.
- Registration of the consignment note for the cargo. After successful acceptance, the carrier's representative or agent begins to form the payload for the suitable flight.

Loading onto an aircraft and securing baggage, mail and cargo are integral parts of the aircraft's commercial support at the starting airport. Responsibility for flight safety and the complexity of operations performed at this stage determines the direct participation of many officials in them.

The main task of this stage of commercial aircraft support is its timely loading in strict accordance with the CG and reliable fastening of baggage, mail and cargo, which is a guarantee of flight safety. Loading and unloading operations at intermediate airports should be carried out with control of the correspondence of the mass and placement of the group load to the calculated data of the CH, compiled at the airport.

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SABRE AIRLINE SOLUTIONS
LOADSHEET        CHECKED   APPROVED      EDNO
ALL WEIGHTS IN KILOGRAMS      D JIMENEZ          1

FROM/TO  FLIGHT    A/C REG VERSION    CREW  DATE    TIME
DFW MIA  U0300/22   5BDAQ  28C213Y   2/10  22FEB07  1031

            WEIGHT      DISTRIBUTION
LOAD IN COMPARTMENTS     3300 1/0 2/0 4/3025 5/275
PASSENGER/CABIN BAG     9169 78/37/13/1 TTL 129 CAB 0
                 CY 6/122 SOC 0/0

TOTAL TRAFFIC LOAD      12469
DRY OPERATING WEIGHT     78815
ZERO FUEL WEIGHT ACTUAL  91284 MAX 111500 L
TAKE OFF FUEL           9750
TAKE OFF WEIGHT ACTUAL  101034 MAX 138600
TRIP FUEL              7750
LANDING WEIGHT  ACTUAL  93284 MAX 121500
TAXI OUT FUEL           250

                  LAST MINUTE CHANGES
BALANCE AND SEATING CONDITIONS DESTSPEC  CL/CPT + -  WEIGHT
BI     -0.1 DOI     -1.5
DLI      1.8 MACDLW  134.5
LIZFW    1.4 MACZFW   28.1
LITOW    2.5 MACTOW   30.1
LILAW    2.0 MACLAW   29.3
AND      0.2
CABIN CLASS  TRIM
C   6  -0.5    Y    122 1.5

UNDERLOAD BEFORE LMC  20216        LMC TOTAL  + -

CAPTAIN:
CAPTAINS INFORMATION/NOTES
BW    76972  BI       -0.1
MATW  139500  RAMP TAXI WEIGHT ACTUAL  101284
CG LIMITS LIZFW  FWD    -3.1 AFT     3.7
      LITOW  FWD    -3.4 AFT     4.1
      LILAW  FWD    -4.1 AFT     4.5
B/   800  C/    2000  M/    200
PANTRY CODE   A     /962
```

Fig. 1.1 - Sample loadsheet

The sheet includes relative information identifying the fuel loads, passengers, cargo and center of gravity calculations.

1.2 Types of aircraft cargo

Requirements for the conditions of air transportation and documentary support, depending on the type of cargo. They are regulated by the existing rules for cargo transportation, taking into account the recommendations of ICAO and IATA.

According to the current regulatory documents, cargo intended for air transportation can belong to the following categories:

- lightweight;
- heavy and oversized;
- for transportation with an accompanying person;
- transfer;
- perishable and heat-sensitive;
- radioactive and other dangerous;
- valuable;
- "Wet" (liquids);
- live goods.

Frequently, the cargo falls into several of the above categories at once, which should be taken into account when packing, storing, loading / unloading, transporting and preparing an accompanying package of documents.

Fig. 1.2 - Aircraft cargo loading process

Lightweight is considered a load, 1 kg of mass of which occupies 8000 cm3 and more in volume. Requirements for the carriage of such goods by air are minimal, if in their other parameters they do not go beyond the standards.

Heavy and oversized category includes shipments weighing more than 80 kg and cargo that exceeds the overall dimensions of the standard loading hatches of passenger aircraft. For their transportation, transport aircraft with suitable characteristics are used. Loading and unloading is carried out at the airport terminals equipped with special rigging equipment. Containers and fastenings for heavy loads must ensure their reliable fixation in the cargo compartment. When loading / unloading oversized cargo, it is required to agree on the time so as not to disrupt the terminal's work schedule.

Transfer air cargo transportation with reloading to another transport aircraft at an intermediate point is carried out only on condition that the transfer airport gives permission and has the ability to send the cargo to the destination within the specified time frame. To clarify this possibility, a preliminary request is made.

If a packaging malfunction is detected at the transfer airport, an act is drawn up, control weighing and repackaging are carried out.

Perishable goods - foodstuffs, vaccines and other medicines, fresh flowers, etc. - are accepted for shipment by aircraft if there are certificates and certificates of the established form (veterinary certificates, quality certificates, etc.). Documents indicating the maximum permissible delivery times must be issued on the day of acceptance of the goods. They are packed in containers that meet the requirements of technical specifications. The carrier must be informed about the sensitivity of the cargo to temperature changes during the flight, loading / unloading, storage.

Radioactive and other dangerous goods. The hazard class - I, II, III - must be indicated (Figure 1.3) on the package with radioactive materials. Depressurization of the package with class II and III radioactive materials is NOT allowed. Radioactive cargo cannot be transported in the same cargo compartment with radiosensitive cargo - photographic films, etc.

Fig. 1.3 - Marking of radioactive cargo

For air transportation of animals, escort and permission from the veterinary service is required. Transportation of livestock and large animals is carried out only with the permission of the head of the SOP. The sender and the accompanying person ensure the availability of transport cages, feed, drinking water, a first aid kit, bedding material and cleaning equipment.

1.3. Unit Load Devices

The ability of cargo units to maintain their integrity and original geometric shape in the process of performing various logistics operations is achieved by packaging.

Packaging is the operation of forming a load unit on a pallet and then tying the load and the pallet into a single whole.

Packaging provides:

- product safety on the way to the consumer;
- the ability to achieve high performance indicators when performing loading and unloading and transport and storage operations due to their comprehensive mechanization and automation;
- maximum use of the carrying capacity and capacity of the rolling stock on all types of transport;
- possibility of reloading without re-shaping;
- safety of loading and unloading and transport and storage operations.

Unit Load Device is a tool for forming and fastening loads into an enlarged cargo unit, as a result of which packing is ensured. The transportation of cargo by cargo in containers or on pallets in the cargo hold of air transport speeds up the process of loading cargo into a cargo plane and provides control over the carrying capacity of the aircraft.

1.4 Types Of Packaging Tools

There are several types packaging tools currently are used.

Bunching cassette - bunching device, consisting of frames, posts and connecting elements (fig.1.4);

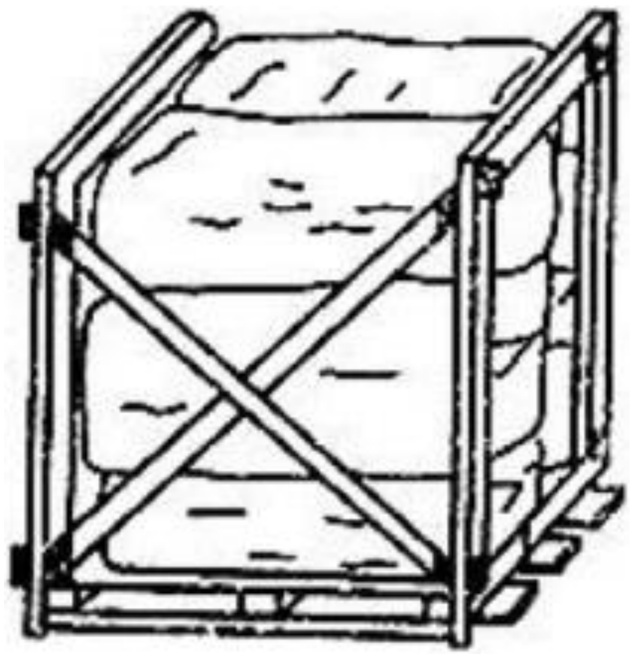

Fig. 1.4 - Aviation bunching cassette

A bundling sling is a bundling device consisting of rigid and (or) flexible elements with a locking device (fig.1.5).

Backing sheet - a means of packaging, which is a solid sheet or with through holes over the area, having a smooth surface with an edge or edges bent upward.

Bunching screed is a semi-rigid bunching device with a clamping device.

Bundling strapping - flexible bundling device in the form of strapping (tape, wire, mesh, film)

Pallet (pallet) - a packaging device with a flooring and, if necessary, a superstructure for placing and securing cargo (cargo). Pallets can be universal and specialized. By types, pallets are flat, comb, box, rack.

Box pallet - a pallet made in the form of a tank with devices for loading and unloading bulk, powdery, liquid and gaseous goods, with an internal volume of up to 1 m³.

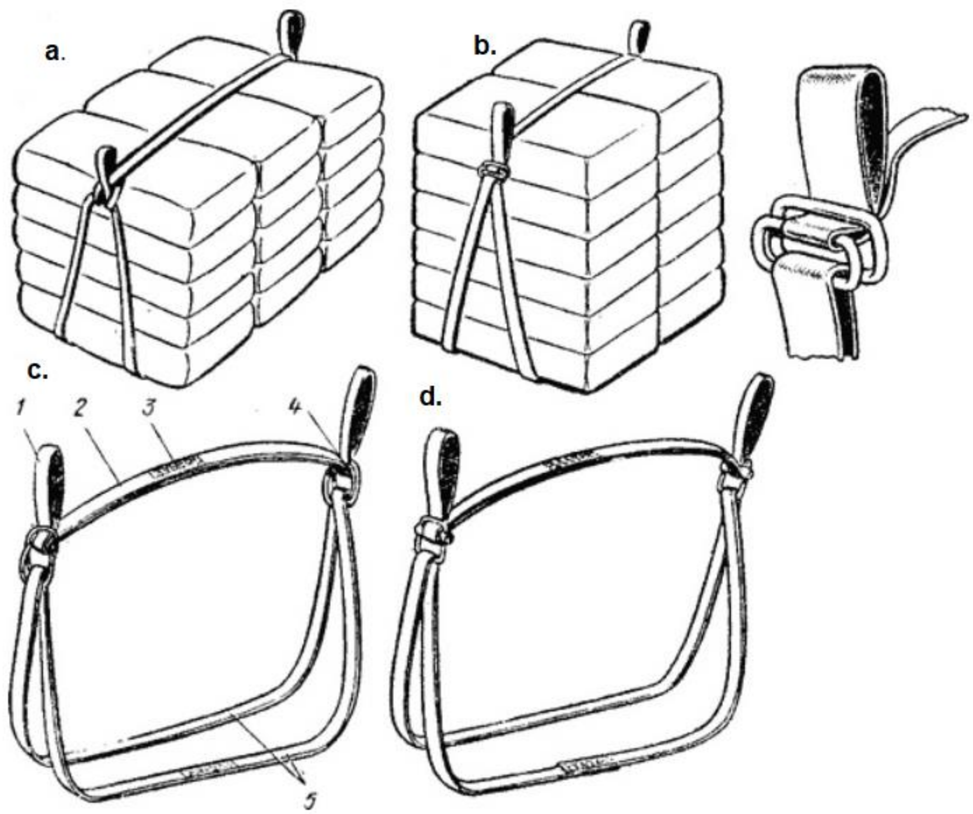

Fig. 1.5 - Double-leg tape slings: a - Without locks; b and c - with ring locks; d - with locks from a frame and a movable structure clamp; 1- lifting loops; 2 - closing branch; 3 - stitching the ends; 4 - a lock of two rings; 5 - supporting branches

1.5 General requirements for the placement of goods

The location of the center of gravity of the aircraft, and therefore the location of the transported cargo, determines the balance, stability and controllability of the aircraft, i.e. safety flight.

To ensure the safety of the flight, when loading the aircraft, it is necessary to withstand limit limits commercial load and its placement in the cargo compartment.

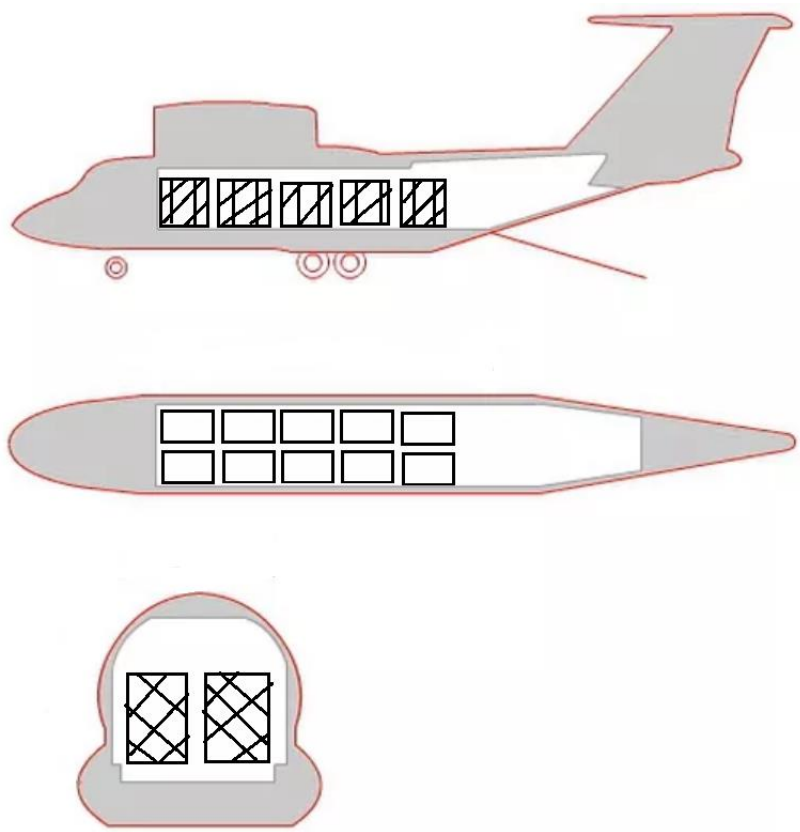

Fig.1.6 - AN-74 cargo loading layout

To exclude recalculations of the centering schedule, it is recommended to perform an estimate placement of goods using a special nomogram. For this, it is necessary to define location of the general center of gravity of the transported goods. If the intersection point is vertical the total center of gravity of the goods and the horizontal line of the total payload is in the zones of permissible location of the common center of gravity along the OX and OZ axes, then the range permissible flight balance of the aircraft will be maintained.

Placing a commercial load on an aircraft must ensure safety in all flight modes.

The location of the general center of gravity of the transported goods is measured along the axis the aircraft and is determined from the equation of the moments of gravity of individual loads relative to, for example, the front point of the cargo compartment.

The coordinate of the general center of gravity of the transported goods is determined by the fraction, number which will be the sum of the products of the weight of each cargo by the distance to the selected point counting, and the denominator is the total weight of the cargo: in the event of a discrepancy between the actual placement of cargo and the aircraft loading scheme it is necessary either to move the goods and achieve full compliance, or to recycle loading scheme according to the actual loading and, if it is ensured that all the limitations weight and balance, the centering graph should be recalculated.

1.6 Basic rules for mooring cargo

To ensure the safety of the flight, after loading the cargo on the plane, it is necessary to securely fasten.

Unsecured loads can spontaneously shift in the aircraft under the influence of weight cargo, operational overloads and aircraft vibrations.

The displacement of the loose under the action of the gravity component occurs when descent and roll of the aircraft. The friction force prevents the load from moving from the floor. At certain angles of inclination of the aircraft, the gravity component directed along floor, there is more friction force, so the loads begin to move along the cargo floor cabins: $mg > Ftr$.

Displacement of an unsecured load under the action of inertial forces equal tothe weight of the cargo for overloading, occurs when moving along the airfield, maneuveringaircraft and flying in a turbulent atmosphere. The displacement of the unsecured load is increased by the vibrations created with running engines, atmospheric turbulence, irregularities in the surface of the aerodrome.

The displacement of the load leads to a change in the alignment of the aircraft and the creation of an emergency in flight. Most often, the displacement of the load occurs during the takeoff run and at the moment the aircraft takes off. Spontaneous displacement of the load is also dangerous because it can cause destruction airframe structure, jamming of moving elements of the aircraft structure, destruction fuel, hydraulic and air conditioning pipelines.

The likelihood of cargo displacement and related destruction on the aircraft significantly increases when flying in a turbulent atmosphere, emergency descent, rough landing. When calculating the forces arising in the mooring chains (ties), the following are taken assumptions:

a) all mooring ties have the same pre-tension and only tensile loads are worn;
b) the forces of friction arising between the cargo and the floor of the cargo compartment are not taken into account;
c) the mooring scheme is performed symmetrically relative to the XOY planed
d) loads and fastenings of mooring nodes are absolutely rigid;
e) the rigidity of the load-bearing floor of the cabin at all points of fastening of the mooring ties is the same new;
f) all mooring ties have the same pre-tension and only tensile loads are affected.

Overloads in some cases can be quite significant, so read mooring of cargo should be calculated for the most severe cases of overload. At this, the load must not collapse and fall from the place of its mooring. The total efforts in the mooring ties are determined by the formula: $S = Sx + Sy + Sz$.

1.7 Solution of cargo loading problem

Since there are many types of cargo described above, it is important to understand what will help speed up the efficiency of loading and unloading an aircraft. The use of a ball bearing floor in the cargo compartment of an aircraft using composite panels is an effective solution. Thus, the load from the load on the balls is evenly distributed without destroying the light and fragile composite panel, in which the BTU is installed (fig.1.7).

This type of auxiliary device for the aircraft cargo compartment will help to speed up the unloading and loading of cargo, since due to the lower friction during loading of the FLD, the loading speed increases. In addition, if the load needs to be moved or rotated within the cab, it is much easier and faster to do this on a ball floor.

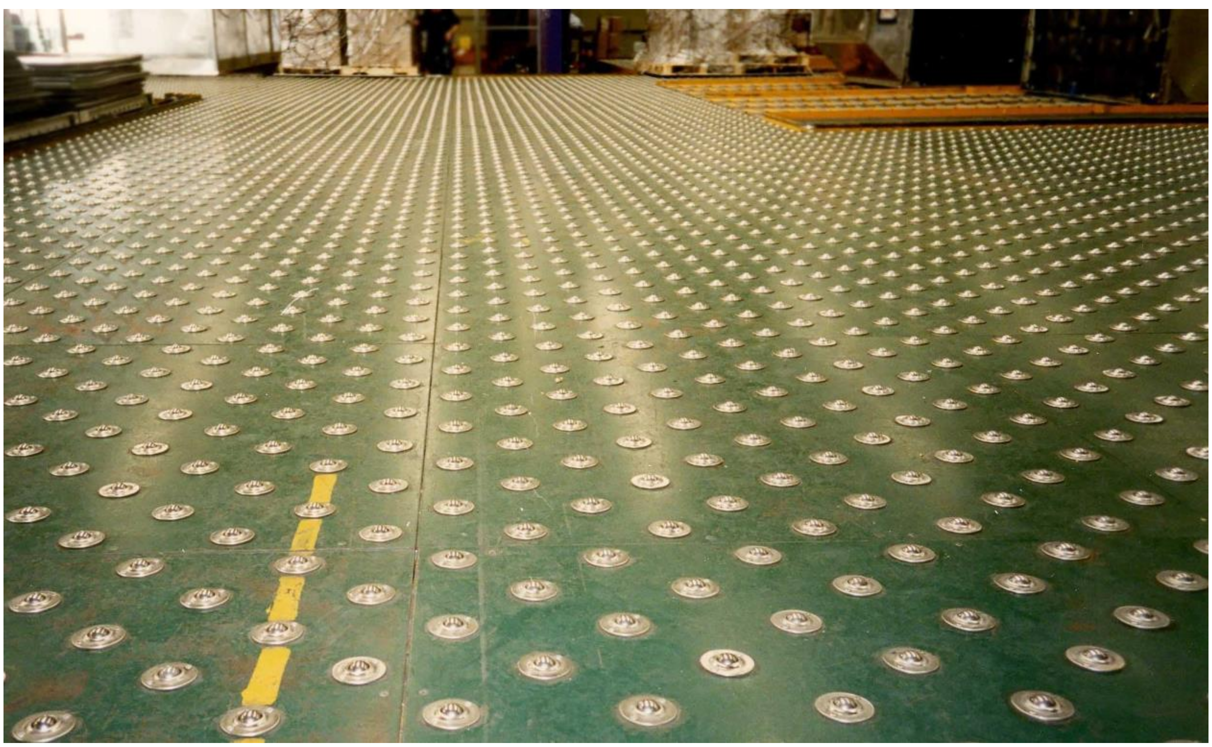

Fig.1.7 - A typical example of ball mat flooring

There are several types of BTUs that fit into the cargo floor panel of an aircraft. Each BTU has its own parameters both in terms of size and specific load (fig.1.7).

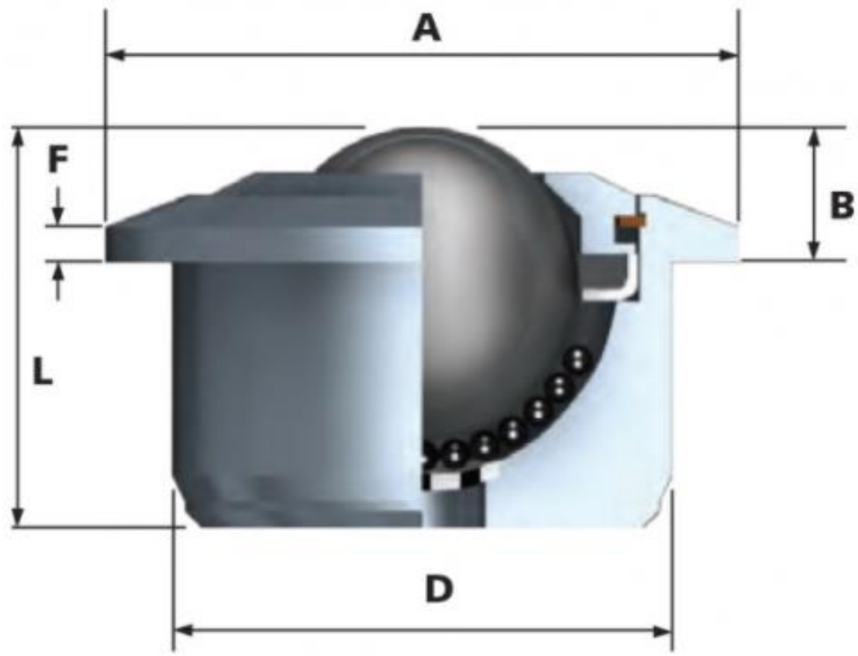

Fig. 1.8 - Ball Transfer Unit parameters

The simplicity of the mechanism provides high reliability, and a large selection permits flexibility in the choice of each element for the equipment of the cargo compartment floor.

Thus, for large but light ULDs, it is possible to install a small number of BTUs in one floor panel. Since the load is not heavy, a large area is not required to distribute the load. In the case of heavy ULDs, an optimal calculation of the specific load for each BTU is required. Accordingly, the device can be installed in different configurations, which allows calculating the number of BTUs in one panel and saving on weight. Such BTUs are installed in a composite panel of the "sandwich" type. (Figure 1.9)

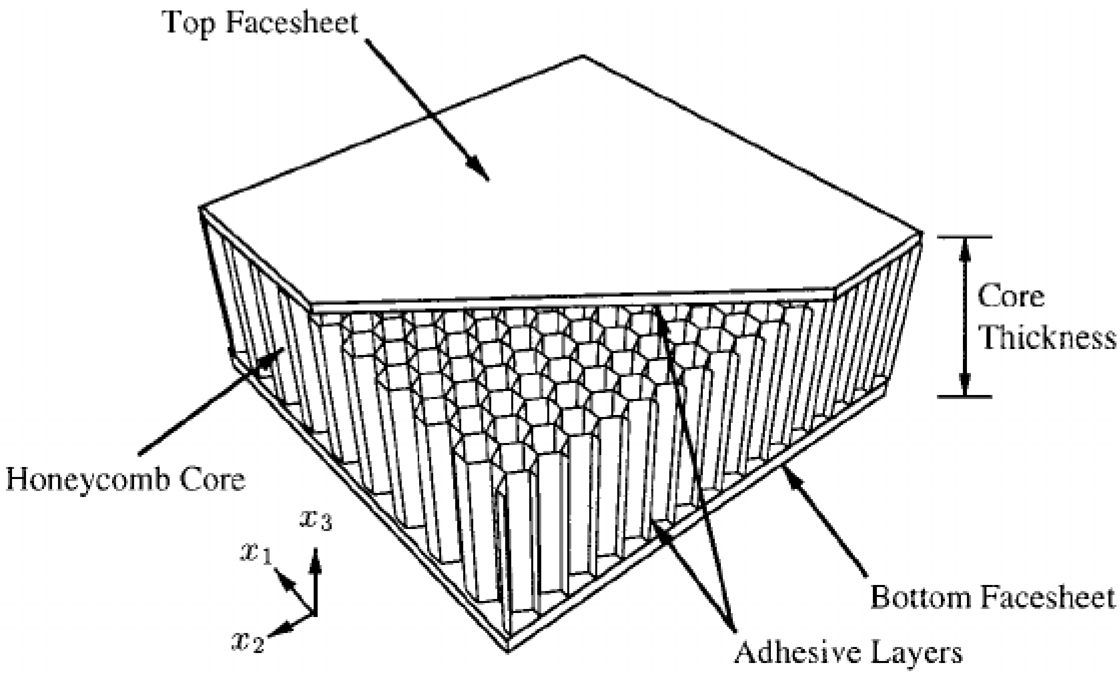

Fig. 1.9 - Sandwich type honeycomb panel

Such a panel is strong enough and at the same time light enough to withstand the load applied to the BTU.

Conclusion to part 1. Aim and objectives of the work.

This section briefly describes the problem of unloading and loading cargo into the cargo hold of an aircraft. The purpose of this section is to understand that detailed improvements and revisions of the aircraft cargo compartment can help, in the current realities of the coronavirus, to deliver cargo faster and in greater quantities.

Main **aim of this diploma work** is to propose ball mat for aircraft cargo compartment. To gain this aim the following **objectives** will be achieved:

1. To derive ball mat design with account of aircraft capacity, expected loads on the floor, cargo compartment geometry and aircraft carcass structural design.
2. To define maximum allowed commercial load on ball mat floor.

3. To provide the strength of the ball mat by adequate calculation and selection of the constructional materials.

Thus, from all of the above, it can be concluded that to simplify the work of service personnel, reduce the weight of the aircraft, and increase the payload, BTUs integrated into the composite floor panels can be used.

This auxiliary mechanism has its advantages over heavy, steel cranes, winches, etc. It also increases the maneuverability of the cargo inside the cargo compartment during redevelopment.

In the end, this type of equipment for the cargo compartment is the most reliable, as it does not use motors and electric circuits. And it is easy enough to calculate, depending on the tasks assigned to this type of aircraft.

PART 2. AIRCRAFT PRELIMINARY DESIGN

2.1 Planes-prototypes

The preliminary design section starts with the summary data related to the previous successful airplanes played an important role designed in Ukraine and abroad.

This section is called “Analysis and Synthesis”. Choosing of the planes-analogous has been carried out by the data of similar function, aerodynamics, takeoff and landing weight, flight speed, flight altitude, cargo capacity, fuel efficiency, etc.

In the field of cargo planes design the Ukrainian Antonov Design Bureau takes special place. Thus, for new airplane preliminary design the cargo aircraft which was produced by Antonov were considered as main one.

The experience of leading foreign aircraft manufactures is taken into account as well.

For the synthesis and analysis, presented in this section of diploma work, the planes AN-72, AN-74, and Boeing YC-14 are considered.

These aircraft were selected and compared because they have similar parameters of engine position, tail unit and wing layout.

It is based on the idea of a short takeoff and landing aircraft with a coanda effect. The Boeing aircraft of this class at one time was not entirely successful as it turned out to be too large and could not equal Antonov's aircraft in terms of maneuverability and economic efficiency.

However, at one time he also performed cargo transportation tasks, but was soon replaced by a not so ambitious project.

Antonov's plane continued to be modernized and flies in the AN-74 modification to this day.

Data required for the selection of basic parameters is presented in table 1.1.

Table 2.1 – Operational-technical data of prototypes

PARAMETER	PLANES		
	An 72	An 74	Boeing YC-14
The purpose of airplane	Cargo	Cargo	Cargo
Crew/flight attend. Persons	3/2	3/2	2/1
Maximum take-off weight, m_{tow}, kg	32 000	30200	77270
Most pay-load, $m_{к.max}$, kg	18260	18000	15000
The height of the flight $v_{w.\ Ек.}$, m	10 100	10 100	13716
Range $m_{к.max}$, km	4700	5700	5136
Take off distance $l_{зл.д.}$, m	800	1000	1200
Number and type of engines	2хД-36	2хД36	2xCF650D
The form of the cross-section fuselage	Circular	Circular	Circular
Extension of the fuselage	2,1	2,3	1,8
Sweepback on 1/4 chord, ^{0}	20	22	15
Commercial load, kg	7400	8000	11000
Cruising speed, km/h	560	580	600
Range with maximum payload, km	1100	1300	800
Bypass ratio	4.7	4.9	4.7
Aspect ratio	7.5	7.5	7.3
Taper ratio	2.67	2.65	2.4
Fuselage diameter, m	3.1	3.1	4
Horizontal stabilizer sweep-back angle, ^{0}	30	30	35
Vertical stabilizer sweep-back angle, ^{0}	35	35	33
Optimal lift force coefficient	0.3	0.35	0.36
Take-off speed, km/h	203	180	170
Lift-off distance, m	611	596	587
Safety altitude distance, m	600	587	576
Full take-off distance, m	1211	1183	1163
Maximum landing weight, kg	30000	28045	70000
Average fuel consumption, kg/h	1653	1566	2364
Specific fuel consumption (take-off)	41.26	39.26	62.33
Specific fuel consumption (cruising)	51.37	51.37	77.45
Take-off thrust of one engine, kn	63,76	63,76	230

As a result of the data presented analysis the primary characteristics for new aircraft have been selected and substantiated.

2.2 Designed aircraft description

Engineers and designers tried to discover ways to build airplane with small run and low speed take-off, due to short airfields and unprepared surfaces.

High wing. A device with a high wing, that is, the wing is above this horizontal plane. Has a swept wing. On the wing, two turbojet engines are installed in the engine nacelles pushed forward. This arrangement of the engines increases lift and provides better takeoff and landing performance. The air flow coming out of the jet engine sticks to the wing, thereby creating the Coanda effect, which allows the aircraft to be thrown upwards and fulfill the main purpose of taking off from the ground at low speed. Lift is created by the pressure difference, which allows the plane to be pushed upward. Thus, the greater the pressure difference on the wing, the stronger the lift force pushes the aircraft upward and at low speeds the coanda effect gives a significant advantage.

The main advantage of using a high-wing layout with engines located above the wing gives the coanda effect and high lift at low speeds, as well as improves aerodynamic characteristics and eliminates stones from entering the engine when landing.

Wing. Low pre-sonic resistance is ensured by the supercritical wing shape as well as by the sweep angle of the wing, especially in this high-wing configuration. Such a wing allows to reduce drag during the actual cruise flight mode, as well as allows you to maintain high lift at low altitudes and low speeds, is well suited for approaching the glide path in unprepared landing sites. Also, the structure has an increased radius of the leading edge of the wing, which makes it possible to increase the wing area and, accordingly, to lift heavy loads at a relatively low speed. As well as Boeing, Antonov’s engineers also decided to combine supercritical airfoil with upper surface blow (USB) of engine.

In Boeing's case, their engineers knew that NASA had already investigated "powered lift" studies some time earlier. Both externally blown flaps, as well an upper-surface blowing (USB), an unusual variation also have already been discovered. In the Boeing aircraft system, the engine is mounted above the wing and blows on the flaps, creating a coandi effect not with the wing plane but with the fowler flaps. Thus, by agreement with NASA, scientific research was carried out in which it was discovered that half-span upper-surface blowing is resulting in high lifting force due to Coanda effect. Studies have also shown that this type of wing in conjunction with an engine is an effective solution and deeper work on this issue began immediately. Boeing built its tunnels to study the Coanda effect and already in 1972 several prototype models were being studied.

The very idea of a vysokoplane with the installation of engines on top of the wing and the use of the coanda effect for rebounding from the airfield during takeoff belongs to the Boeing company. Since at this time there was a cold war and virtually all developments were adopted from other countries, the Antonov plant simply improved this technology.

The advantages of such a scheme are:

- streamlining without stalling at large angles of attack

- high engine position prevents runway debris from taking off and landing

- less load on the fuselage

-best directional stability

Engine CF6-50. CF6 is a family of turbofan jet engines of the American company GE Aviation. Developed with TF39 engines for Lockheed C-5 Galaxy, the world's first turbofan engine. In the late 1960s, the CF6, a more powerful version of the military TF39, was offered to aircraft manufacturers Lockheed for the new wide-body L-1011 TriStar and McDonnell Douglas for the DC-10. The first manufacturer settled on the Rolls-Royce RB211, and the second chose the new product from General Electric. To consolidate the success of the McDonnell Douglas DC-10-10, an extended range version was required, and General Electric received an order for a more powerful CF6-6 counterpart. By refusing to increase the temperature at the inlet to the high-pressure turbine (due to material limitations), GE chose an extensive path: reconfiguring the original engine to increase its displacement. The two rear stages of the high pressure compressor were removed (resulting in an empty space where the blades and coils were), in return - two stages were added to the low pressure compressor immediately following the fan. The compression ratio was increased to 29.3. The same fan, spinning up faster, already pumped 660 kg / s, reaching a thrust of 226.86 kN. But the bypass ratio dropped to 4.26, which led to an increase in fuel consumption. However, in the 1970s, this was not as defining as it is today. By the end of 1969, the CF6-50 was selected for the new European wide-body Airbus A300 (Air France became the first customer in 1971). In 1975, KLM first ordered a Boeing 747-200 with CF6-50 engines, followed by an order from All Nippon Airways for Boeing 747-100BSR aircraft with increased passenger compartment capacity, but reduced power and range - for use on high-load domestic Japanese lines. For this, the CF6-45 version was created with a 10% less thrust. The CF6-50 series are high-bypass turbofan engines rated between 51,000 and 54,000 lb (227.41 to 240.79 kN, or '25 tons') of thrust. The CF6-50 was developed into the LM5000 industrial turboshaft engines. It was launched in 1969 to power the long range McDonnell Douglas DC-10-30, and was derived from the earlier CF6-6. Not long after the -6 entered service, an increase in thrust and therefore core power was required. Unable to increase (HP) turbine rotor inlet temperature, General Electric chose the expensive path of reconfiguring the CF6 core to increase its basic size.

Engine Lotarev D-36. D-36 turbojet engines of series 1, 2a, 3a are intended for use on Yak-42 passenger aircraft and for An-72 and An-74 transport aircraft.

The main advantages of the D-36 turbojet engines:

- low specific fuel consumption;

- high reliability;

- great resource;

- low levels of noise and emission of pollutants;

- simplicity and manufacturability of maintenance, high maintainability, provided by modular design;

- the presence of a universal suspension, which allows it to be used on various aircraft without changes in the design of the engine; - by placing the engine under or above the wing, in the aircraft fuselage or on both sides of it.

Empennage. A powerful fin is installed on the aircraft to ensure directional stability. The rudder has an original two-hinged design, which increased its efficiency at low speeds, and is divided into two sections in height. The lower rear of the steering wheel is controlled directly by the pedals of the pilot, and the rest - by boosters of the control system.

Undercarriage. The choice was made towards a retractable chassis with steerable front chassis and four large independent suspension wheels. Such a landing gear scheme gave advantages when landing an aircraft on unprepared airfields. And she could also allow to take a large load and how to sit down with it and take off.

2.3 Aircraft geometry

The geometrical parameters are found on the base of the calculations results presented in table 1.1.

2.3.1 Wing geometry calculation

Geometrical characteristics of the wing are determined from the take of weight m_0 and specific wing load P_0.

Wing loading value has been accepted on the base of similar planes analysis.

For the designed plane it was chosen to be equal to 148,54 kg/m^2

From this:

Full wing area with extensions is:

$$S_{wfull} = \frac{m_0 \cdot g}{P_0} = \frac{91295 \cdot 9.8}{4153} = 215.43 \ (m^2)$$

The foolowing wing parameters were found:

- Relative wing extensions area is 0.1;

- Wing area is: S_w=107.5 [m^2] ;

- Wing span is: l_w=31890 [m];
- Root chord is: b_0=4.55 [m];
- Tip chord is: b_t=1.500 [m].

On board chord for trapezoidal shaped wing is:

b_{ob}=4.241 [m].

Taking into account the main parameters of the wing, according to the calculations made, the following parameters were selected.

Aspect ratio. Increasing wing aspect ratio is one way to reduce inductive drag. For this reason, the wings of record gliders are made as long and narrow as possible. However, this path has limitations. The first limitation is due to the fact that doubling the aspect ratio of the wing leads to a fourfold increase in the loads on the wing spar.

The second reason is that in order to maintain the same angle of attack along the entire length of the wing, it must have sufficient torsional stiffness. Otherwise, flutter may occur. The greater the wing elongation, the more difficult it is to provide the required stiffness.

Some examples of the aspect ratio values are presented in table 1.2.

For proposed plane the value of aspect ratio 7.5 has been selected.

Table 2.2 - Aircraft wing aspect ratio examples

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

The taper ratio of the wing has been selected equal to 2.67 as aresult of the following considerations:

a) The planform shape should not give rise to an additional lift distribution that is so far from elliptical that the required twist for low cruise drag results in large off design penalties; b) The chord distribution should be such that with the cruise lift distribution, the distribution of lift coefficient is compatible with the section performance. Avoid high Cl's which may lead to buffet or drag rise or separation; c) The chord distribution should produce an additional load distribution which is compatible with the high lift system and desired stalling characteristics;

Here, again, a diverse set of considerations are important. The major design goal is to keep the taper ratio as small as possible (to keep the wing weight down) without excessive Cl variation or unacceptable stalling characteristics.

Since the lift distribution is nearly elliptical, the chord distribution should be nearly elliptical for uniform Cl's. Reduced lift or t/c outboard would permit lower taper ratios. The thickness to chord value has been selected equal to 0.140 because: We would like to make the t/c as large as possible to reduce wing weight (thereby permitting larger span, for example); b) Greater t/c tends to increase CLmax up to a point, depending on the high lift system, but gains above about 12% are small if there at all; c) Greater t/c increases fuel volume and wing stiffness; d) Increasing t/c increases drag slightly by increasing the velocities and the adversity of the pressure gradients;

The sweep back angle has been selected equal to 22 degrees. The purpose of the swept back angle is an increase in the speed at which the wave crisis sets in, and as a result, less resistance at transonic speeds in comparison with a straight wing.

At a choice of structural scheme of the wing we determine quantity of spars and their position, and the places of wing portioning.

On the modern transport planes two spars or three spars designs are most conventional. The two spars design have been selected as appropriate.

I use the geometrical method of mean aerodynamic chord determination (figure 1.1). Mean aerodynamic chord is equal: b_{MAC}=3.281 [m].

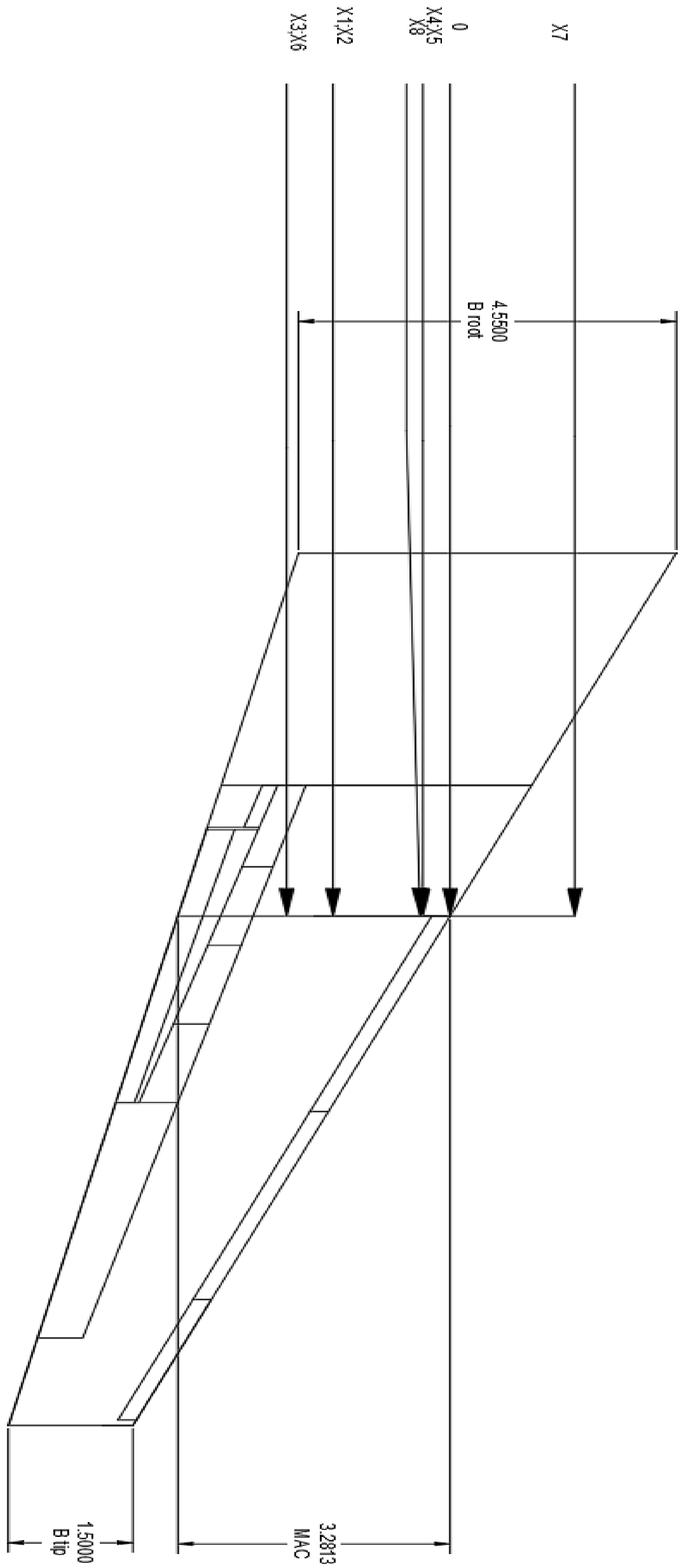

Fig. 2.1 - Detrmination of the mean aerodynamic chord

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

Ailerons geometrical parameters are determined in next consequence:

- Ailerons span: l_{ail}=5.98 [m];
- Aileron area: S_{ail}=3.493 [m^2];

Increasing of l_{ail} and b_{ail} more than recommended values is not necessary and convenient. With the increase of l_{ail} more than given value the increase of the ailerons coefficient falls, and the high-lift devices span decreases. With b_{ail} increase, the width of the xenon decreases.

In the airplanes of the third generation there is a tendency to decrease relative wing span and ailerons area. In this case for the transversal control of the airplane we use spoilers together with the ailerons. Due to this the span and the area of high-lift devices may be increased, which improves take off and landing characteristics of the aircraft.

Aerodynamic compensation of the aileron.

Axial $S_{axinail} \leq (0.25…0.28)\ S_{ail}$ =0.908 [m^2].

Inner axial compensation $S_{inaxinail}$ = (0.3..0.31) $S_{ail=}$ 1.047 [m^2];

Area of ailerons trim tab.

For two engine airplane: S_{tail}=0.174.

Range of aileron deflection

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

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

The aim of determination of wing high-lift devices geometrical parameters is the providing of take of and landing coefficients of wing lifting force, assumed in the previous calculations with the chosen rate of high-lift devices and the type of the airfoil profile.

Taking into the account the design of planes-prototypes and current trends in the design of high lift devices the Coanda effect double slotted flaps design has been proposed.

Layout and geometrical parameters determination of wing high-lift devices. The main aim of this chapter is the providing of take of and landing coefficients of wing lifting force, assumed in the previous calculations with the chosen rate of high-lift devices and the type of the airfoil profile.

Before doing following calculations it is necessary to choose the type of airfoil due to the airfoil catalog, specify the value of lift coefficient C_{ymaxbw} and determine necessary increase for this coefficient $\overline{C}_{y\max}$ for the high-lift devices outlet by the formula: $\Delta\overline{C}_{y\max} = (C_{y\max l} / C_{y\max bw})$.

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

Effectiveness of high-lift devices (C^{*}_{ymaxl}) rises proportionally to the wing span increase, serviced by high-lift devices, so we need to obtain the biggest span of high lift devices ($l_{hld} = l_w - D_f - 2l_{ail} - l_n$) due to use of flight spoiler and maximum diminishing of the are of engine and landing gear nacelles.

During the choice of structurally-power schemes, hinge-fitting schemes and kinematics of the high-lift devices we need to come from the statistics and experience of domestic and foreign aircraft construction. We need to mention that in the majority of existing constructions elements of high-lift devices are done by single spar structural scheme.

2.3.2 Fuselage layout

Based on the main tasks performed by the designed aircraft, the fuselage was designed to withstand the loads that affect it at subsonic speeds (V < 800 km/h).

During transonic and subsonic flights, the shape of the nose of the fuselage affects the wave resistance Cxw. So the fuselage aspect ratio:

$$\lambda_f = 2.1.$$

According to cruising speed and taking into account wave resistance, fuselage nose part has to be:

$$L_{nfp} = 6.51 \text{ [m]}.$$

Since the prototype is a short take-off and landing airplane, considering the loads acting on the fuselage, I took the circular cross-section shape of the fuselage.

The fuselage has a small diameter and since the plane is a cargo plane, I decided to lengthen the fuselage to accommodate a larger commercial load. The main task of the fuselage in this prototype is to remove and distribute the load from the wing to the fuselage, providing space for useful loads. Based on this parameters fuselage length:

$$l_f=25.735\ [m].$$

From the design point of view it is convenient to have round cross section, because in this case it'll be the strongest and the lightest. But for passenger and cargo placing this shape is not always the most convenient one. In the most cases, one of the most suitable ways is to use the combination of two circles intersection, or oval shape of the fuselage. We need to remember that the oval shape is not suitable in the production, because the upper and lower panels will bend due to extra pressure and will demand extra bilge beams, and other construction amplifications.

Since the unloading and loading ramp is intended, among other things, for dropping cargo in flight, it rolled back along the guide under the fuselage. That is cause length of the fuselage rear part is equal:

$$l_{frp}=6.51\ [m].$$

Step of normal bulkhead in the fuselage construction is in the range of 360...500mm, depends on the fuselage type.

2.3.3 Layout and calculation of basic parameters of empennage

To maintain the controllability of the aircraft in flight and its stable behavior, the tail was selected with a T-shape and large fances were installed on the sides of the tail, reducing harmful interference.

Area of vertical tail unit is equal:

$$S_{vtu}=19.35\ [m^2].$$

The stabilizer mounted on top of the fin was outside the bevel of the stream behind the wing, and to ensure a larger range of working angles of attack, it was made interchangeable.

Area o horizontal tail unit is equal:

$$S_{htu}=26.875\ [m^2]$$

The stabilizer profile with a flat top surface and the installation of a deflector along the leading edge eliminates the risk of stall conditions.

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

- Low wing, EonW, M<1, $h_{bo}=(0.14..0.2)l_w$;
- Engine in the root part of the wing, $h_{bo}=(0.13..0.165)l_w$;
- Engine in the tail part, $h_{bo}=(0.13..0.14)l_w$

Altitude elevator area: $S_{el}=7.43\ [m^2]$;

Rudder area:$S_{rud}=4.52\ [m^2]$.

To ensure directional stability, a powerful keel is installed on the plane. The rudder has an original double-hinged design, which increased its efficiency at low speeds, and is divided into two sections by height.

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

Tapper ratio of horizontal and vertical tail unit we need to choose:

For planes M<1 $\eta_{htu}=2...3$; $\eta_{vtu}=1…3.3$.

The area of elevator trim tab:

$$S_{te}=0.5944\ [m^2];$$

Area of rudder trim tab is equal:

$$S_{tr}=0.2712\ [m^2];$$

Root chord of horizontal stabilizer is:

$$b_{0htu}=5.46\ [m];$$

Tip chord of horizontal stabilizer is:

$$b_{t\ htu}=2.730\ [m];$$

Root chord of vertical stabilizer is:

$$b_{0vtu}=1.523\ [m];$$

Tip chord of vertical stabilizer is:

$$b_{t\ vtu}=0.662\ [m].$$

2.3.4 Landing gear design

Only a part of the parameters can be determined at this stage, since the center of gravity of the aircraft has not yet been calculated and there is no drawing of the general sweep of the aircraft.

The object of the invention is to simplify the design with a minimum volume occupied by the chassis in the retracted position.

Landing gear wheel base:

$$B = 8.190\ [m].$$

Front wheel axial offset will be equal:

$$d_{ng}=7{,}313\ [m].$$

Wheel track is: T=4.140 m.

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

In particular, a chassis is known comprising a rack with a folding strut, a wheeled cart with a heel shock absorber pivotally connected to the rack by means of a lever, and the chassis is equipped with a trolley reversal mechanism consisting of a lower rocker and an upper two-arm rocker connected by a rod. The upper two-armed rocker is pivotally attached to the rack and is connected to the pull rod by one arm, and is connected to the lower rocker by the other arm by means of the pull rod.

The load on the wheel is determined:

K_g = 1.5...2.0 – dynamics coefficient.

Nose wheel load is equal:

$$P_{NLG}=30867.92\ [N].$$

Main wheel load is equal:

$$P_{MLG}=40218.275\ [N].$$

Table 2.3 – Aviation tires for designing aircraft

Main gear		Nose gear	
Tire size	Ply rating	Tire size	Ply rating
1050x400mm	18	720x310 mm	14

2.4 Engine selection

Turbofan engines with a high degree of bypass allow to implement the Coanda effect in practice. D-36, created in the Design Bureau of Progress by V.A. Lotarev, provided sufficient air flow, and, which is especially valuable, a relatively "cold" exhaust stream of gases directed to blowing the wing.

Table 2.4 – Examples of application Д-30КУ(КП)

Model	Thrust	Bypass ratio	Dry weight
Д-36	63.75 kN	5.6:1	1124 kg
Д-36 series 1A/2A	63.75 kN	5.6:1	1124 kg
Д-36 series 3A	63.75 kN	5.6:1	1124 kg

2.5 Aircraft center of gravity calculation

The aircraft alignment is determined in the course of its volumetric and weight layout. The design position of the aircraft center of mass must provide the necessary stability and controllability in all flight modes. Longitudinal stability of an aircraft is determined by the relative position of the center of mass and focus of the aircraft.

There are three possible cases of the location of the center of mass and focus of the aircraft:the center of mass is in front of the focus, center of mass aligned with focus, the center of mass is in front of the focus

The example list of the mass objects for the aircraft, where the engines are located on the upper surface of wing, included the names given in the table 1.4.

Determination of the mass power of the equipped fuselage.

Origin of the coordinates is chosen in the projection of the nose of the fuselage on the horizontal axis. For the axis X the construction part of the fuselage is given. The example list of the objects for the aircraft, which engines are mounted to the upper surface of wing, is given in table 1.5.

The centre of gravity (C.G.) coordinates of the fully equipped fuselage are determined by formulas:

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

$$Y_f = \frac{\Sigma m_i^/ Y_i^/}{\Sigma m_i^/}$$

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

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

$$X_{MAC} = \frac{m_f \cdot X_f + m_w \cdot x_w - m_0 \cdot C_n}{m_0 - m_w} = 6{,}45\,(m)$$

Knowing the wings position relatively to fuselage on the layout drawing, we connect the wings power elements and the fuselage. After the wings and fuselage arrangement a C.G. calculation takes place. C.G. positioning is called the relative position of centre of masses relatively to MAC leading edge.

Table 2.5 - Trim sheet of equipped fuselage masses

N	Object name	Mass		C.g. Coordinates X_i, m	Moment of mass $M_i^/ x_i$, kg • m
		Units	Total mass m(i)		
1	Wing (structure)	0,118	4363,275	1,410	6155,839
2	Fuel system	0,001	55,831	1,410	78,768
3	Airplane control, 30%	0,002	101,377	1,968	199,571
4	Electrical equipment, 30%	0,002	80,808	0,328	26,513
5	Anti-ice system , 70%	0,012	462,810	0,328	151,848
6	Hydraulic systems , 70%	0,016	595,042	1,968	1171,400
7	Power plant	0,084	3087,240	-1,5	-4630,860
8	Equipped wing without landing gear and fuel	0,238	8746,385	0,360	3153,080
9	Nose landing gear	0,009	363,930	-6,59	-2398,303

Continuation of Table 2.5

N	Object name	Mass		C.g. Coordinates X_i, m	Moment of mass $M_i^{/} x_i$, $kg \bullet m$
		Units	Total mass m(i)		
10	Main landing gear	0,039	1454,547	1,804	2624,003
11	Fuel	0,13	4844,451	1,410	6834,697
	Total	0,419	15409,316	-3,375	10213,47

Table 2.6 - C.G. positioning sheet

Object name	mass in Kg, m_i	coordinate X_i,, м	mass moment Kg.m
Equipped wing (without fuel and landing gear)	8746,385	6,812	59583,34
Nose landing gear (extended)	363,930	0,861	313,646
Main landing gear (extended)	1454,547	8,255	12008,51
Reservefuel	931,232		
Fuel	4844,451	7,862	38090,31
Equipped fuselage (without payload)	11609,934	9,848	114341,9
Cargo	8405,522	12,687	106645,1
Crew	375	3	1125
Nose landing gear (retracted)	363,930	0,861	313,646
Main landing gear (retracted)	1454,547	6,451	9384,504

Table 2.7- Airplanes C.G. position variants

№	Name	Маса, m_i kg	mass moment $m_i X_i$	center of mass $X_{цм}$	center X_C %
1	Take off mass (L.G. extended)	36730	294017,491	8,004	0,230
2	Take off mass (L.G. retracted)	36731,004	282008,954	7,677	0,323
3	Landing weight (LG extended)	31885,548	294017,491	9,222	0,167
4	Ferry version	28325,482	175363,924	6,191	0,02
5	Parking version	22549,798	186247,431	8,259	0,151

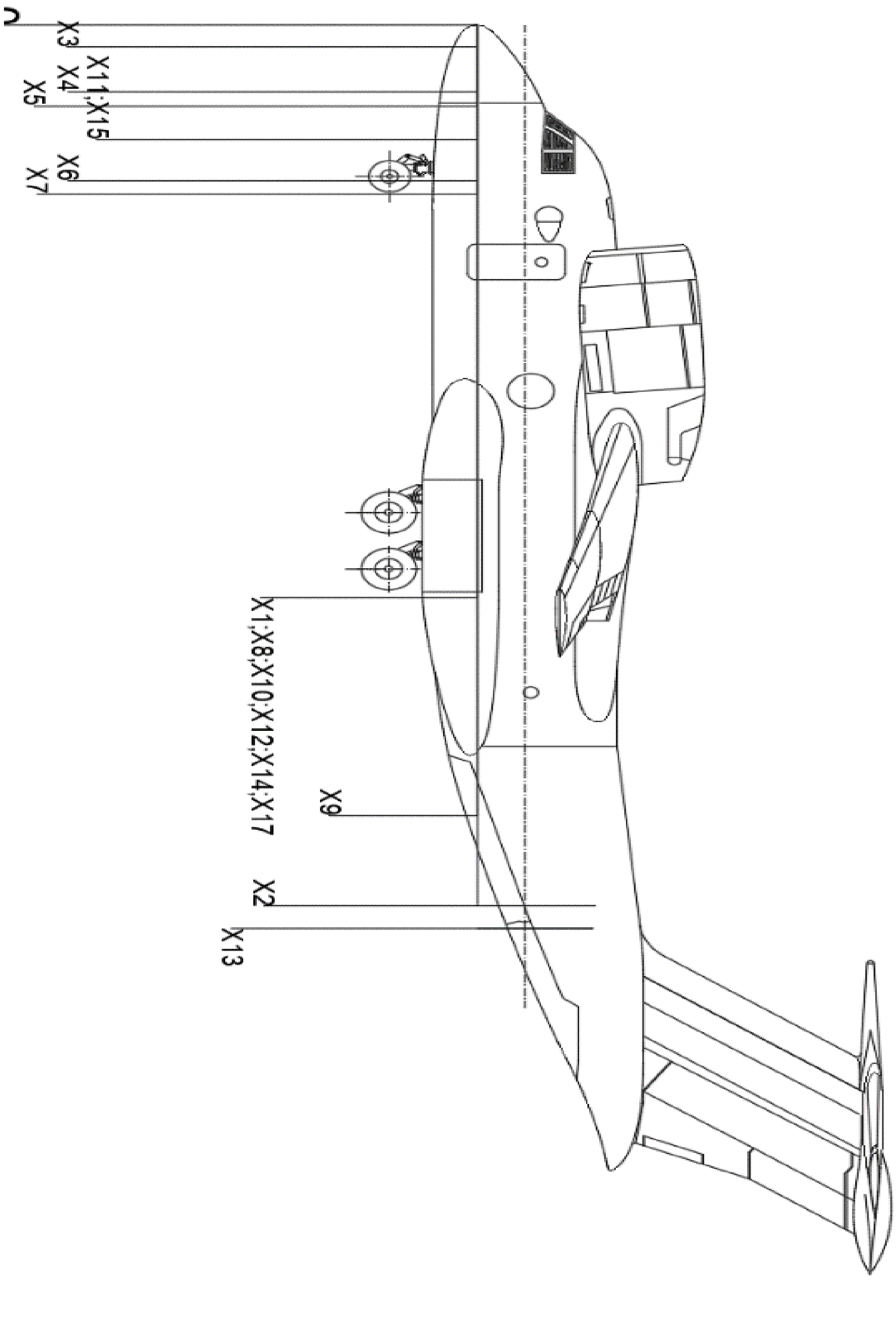

Fig. 2.2 - Fuselage components centers of mass

PART 3. CONCEPT OF THE BALL MAT FOR AIRCRAFT CARGO COMPARTMENT

3.1 Description of the ball mat

The ball pulley is used for transportation and movement of various loads weighing, as a rule, up to 120kg / m. A ball floor is a metal floor with a perforated top. Steel ball bearings are installed in the openings of the tabletop, which provide free movement of loads in any required direction. The ball floor is designed for quick sorting and redirection of goods in the cargo compartment of the aircraft during the unloading / loading process. Plus, it is widely used as an independent work unit, for example, in packaging operations.

The advantage of a ball floor in comparison with roller tables and roller floors is the safety of the load, its integrity, during manipulations with it, due to the integrity there are no gaps. The ball floor is a prefabricated unit, the number of ball bearings, their diameter depends on the size and mass of the cargo being moved. The heavier the load and the smaller the dimensions, the more the number of ball bearings will be in one running meter of the floor. Ball floor is simplicity and ease in moving any kind of dirt in the plane.

Ball tables consist of a metal frame. Its dimensions are selected taking into account the dimensions of the transported sheet materials. Balls are fixed in the body, used as supporting elements for transported goods. During transportation, they rotate in different directions, ensuring the movement of the sheets in the right direction. This design of ball tables allows you to ensure the movement of the load on the plane. Freight traffic redistribution is done manually.

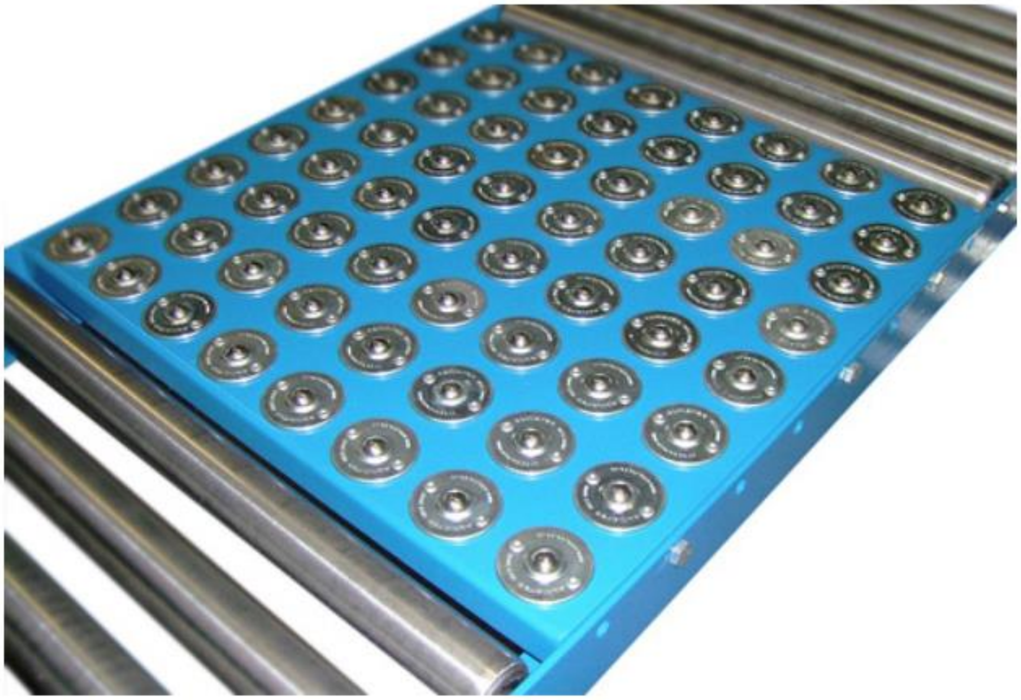

Fig. 3.1 - Typical example of ball mat

3.2 Ball mat principle of work

In this diploma work the ball mat floor for short take off and landing aircraft cargo compartment is represented. A ball mat for the loading deck of an aircraft is a known device to support cargo and assist the movement there of.

It works in the way that a loader will move a container into the aircraft through one of the large cargo doors. Inside the cargo compartment it is a ball mat a device in the floor of the cargo hold that will pull the container all the way in the end then start it on its way to the correct location, where it is locked. The container is moved forwards or backwards by motorized rollers in the floor, the so-called PDUs (Power Drive Units).

Fig. 3.2 - Typical example of PDU

Ball mat:

1) Are omni-directional load-bearing spherical balls placed inside a restraining structure. They are identical in principle to a ball computer mouse upside-down, or a trackball, except there is an array of them side-by-side.

2) Typically the design is contain a single large ball supported by smaller ball bearings. They are commonly used in an inverted ball up position where objects are quickly moved across an array of units, known as a ball mat, as a type of conveyor system. This permits a transfer to and from aircraft cargo compartment.

3) Prior to the invention of the ball transfer unit, first patented by Autoset Production Ltd in 1958, these applications were solved by the use of inverted casters. However, casters recognize a trail, meaning that the wheels had to align before directional change could be achieved.

Ball transfer units also are used as non-inverted ball down position and is a type of mechanism, this use is restricted by load-bearing limitations that and the type of floor.

Compared to purely manual loading, power drive units (PDU) make ground operations more efficient. A Power Drive Unit is used to convert electrical or hydraulic power into mechanical motion (often rotary) and drive a mechanical actuation system. PDUs add considerable weight to the OEW and require power during ground operations. There are floor mounted and track mounted PDUs. The latter are small enough to fit into trays and are lighter, but have to be provided at a greater numbers.

The quality of rubber top coat of the smaller rollers is essential for success operation. To allow ULD movement in all directions and rotation necessary in door areas, there are steerable floor-mounted PDUs. Alternatively, a set of PDUs in perpendicular layout can be installed.

A centralized control unit is install to ensure efficient and safe operation and only PDUs needed to move ULDs at their actual position are powered. Spacing of PDUs is a tradeoff between the number and weight of all PDUs. Tray mounted PDUs may be spaced much wider. If spacing is not wide enough, badly warped ULDs with bent base edges may stall as PDUs lose contact and friction with the ULDs during transport. In wet conditions, a poor ULD contact with the PDUs may cause conveying difficulties.

Figure 3.3 shows the empty cabin looking aft from the doorway on the right. The cabin can accommodate six cargo pallets or five seat pallets plus one pallet-mounted galley unit. In the foreground is the ball mat which placed the doorway pallet position and provides for a 90 degree change of direction as pallets are loaded and unloaded. The galley unit is loaded in this doorway position on the ball mat. The cabin floor aft of the doorway carry out four longitudinal roller tracks with six lateral rows of four pallet locks which is give restraint in forward, aft and vertical directions.

Fig. 3.3 - Ball mat in cargo compartment

3.3 Ball mat design

Nowadays there is no well-known solution for loading cargo in and out of aircraft cargo compartment from door to floor areas. The existing solution for aircraft without significantly sloped doorway floor areas is a doorway area surface referred to as a ball mat.

These allows for the plane movement of cargo in four directions. These balls are also called as Ball Transfer Units (BTUs) which are spaced 6 inches from each other. The ball mat is mounted instead the airplane floor. The main problem of typical rolled mat is that after cargo is in compartment you can not move it or rotate. Rolled floor provides movement only forward and backward directions. In case quick load/unload of cargo is needed ball mat floor is the best decision.

3.4 Calculation of ball mat panel

In prototype length and width of cargo compartment is calculated. Using these data the ball mat floor panels are placed. First of all the installation of ball mat panel which is meter in length and meter in width was chosen. Advantages of this size of mat is in placing on aircraft frames and longitudinal beams. In designing short take-off and landing cargo aircraft spars have step 500 mm, so one ball mat plane places on two spars. So area of cargo compartment is calculated as follows:

$S_{c.c.}$=. $L_{c.c.}$* $W_{c.c.}$=10.5 * 2.15 = 22.57 (m^2)

Maximum commercial load of designed aircraft is 7.5 tons or 7500 kg, so using this parameter with area of cargo compartment specific load on floor is equal:

P_f = $P_{c/}$ $S_{c.c.}$ = 7500/22.57 = 332,29 (kg/m^2)

For ease and practice of calculation square meter panels where chosen.

3.5 Determination of ball mechanism type

Taking into account principal importance of weight on aiplane the optimal ball mechanism in ball mat panel choice is required. Since all ball mat panels have standard balls diameter and materials - hi-tech, double seal ball structure 6025-5 was chosen (Table 3.1).

A typically ball mat contains a composition of roller balls which have next data:

- One inch diameter main spherical balls;

- each one inch ball supported by one eight inch diameter bearing

Table 3.1 - Types of Hi-tech double seal ball transfer units

6025-0	6025-1	6025-2	6025-3	6025-4	6025-5
High load Capacity. Dimensionally compatible with Hevi-Load 7121.	Bolt fixing high load capacity. If used for height adjustment the locknut must remain secured to the body.	Top flange high load capacity. Dimensionally compatible with Hevi-load 7125.	High load capacity. Ball height compatible with Hevi-load 7123.	High load capacity. Coned flange for smoother onoff transfer.	Ideal for shock loading. Stainless steel springs available on request.

The advantages of such ball transfer units are:

- Double sealing. Prevent debris on the bearings appearance;
- The top cover seal removes larger particles;
- the inner knife edge scraper seal skims liquid, paste, etc.
- expels liquid, paste, fine dust through side vents;
- a dirt exit hole can also be incorporated;
- chemical resistance. High resistance to organic solvents, petrol and oil;
- temperature. -30ºC upto +100ºC.

Choice of a such ball transfer unit mechanism is explained by materials which are used. The Hi-tech units have glass re-inforced nylon bodies so their weight is less than half that of the Ø25.4mm Heavy-Load units. Scheme of such BTU is represented on figure 3.4.

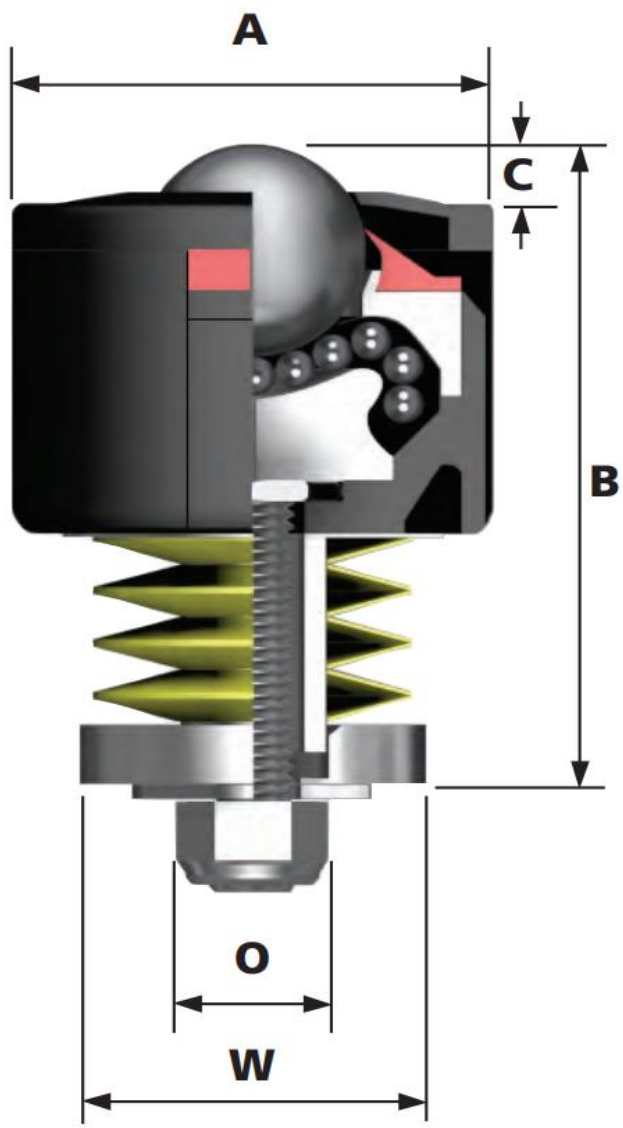

Fig. 3.4 - Stainless Steel Spring Double Seal BTU

From the given data of variants and types of 6025-5 ball transfer units before choosing the load on one ball calculation is needed. Geometrical data and dimensions of such BTUs are represented in table 3.2.

Table 3.2 - Geometrical parameters and dimensions of BTUs

Ref no.	Ball size (mm)	Maximum diameter (mm)	Working height of ball (mm)	Collar diameter (mm)	Dynamic support load (kg)
6025-5-13A	25.4	50.8	61.9	38	7
6025-5-13B	25.4	50.8	61.5	38	23
6025-5-13C	25.4	50.8	60.7	38	45
6025-5-13D	25.4	50.8	61.9	38	70
6025-5-13E	25.4	50.8	81.0	38	90
6025-5-13F	25.4	50.8	79.8	38	140
6025-5-13G	25.4	50.8	81.0	38	180
6025-5-13H	25.4	50.8	81.0	38	230

As BTU panel dimensions are estimated to distribute sixteen BTUs on it is correct decision. Distance between ball units 200mm was chosen. Also calculations are needed to provide equal distances between BTUs on different panels. Distance from center to center is equal:

$L_c = B_p / n_{BTU} = 1000/4 = 250$ (mm),

where B_p is width or length of panel and n_{BTU} is numbers of BTUs.

It is imposible place BTUs to the edges of panel as it causes no distance between them at the junction of panels. So the distance from center of BTU to edge is calculated as follows:

$L_e = L_c / 2 = 250 / 2 = 125$ (mm).

Calculated placing of BTUs are shown on figure 3.5

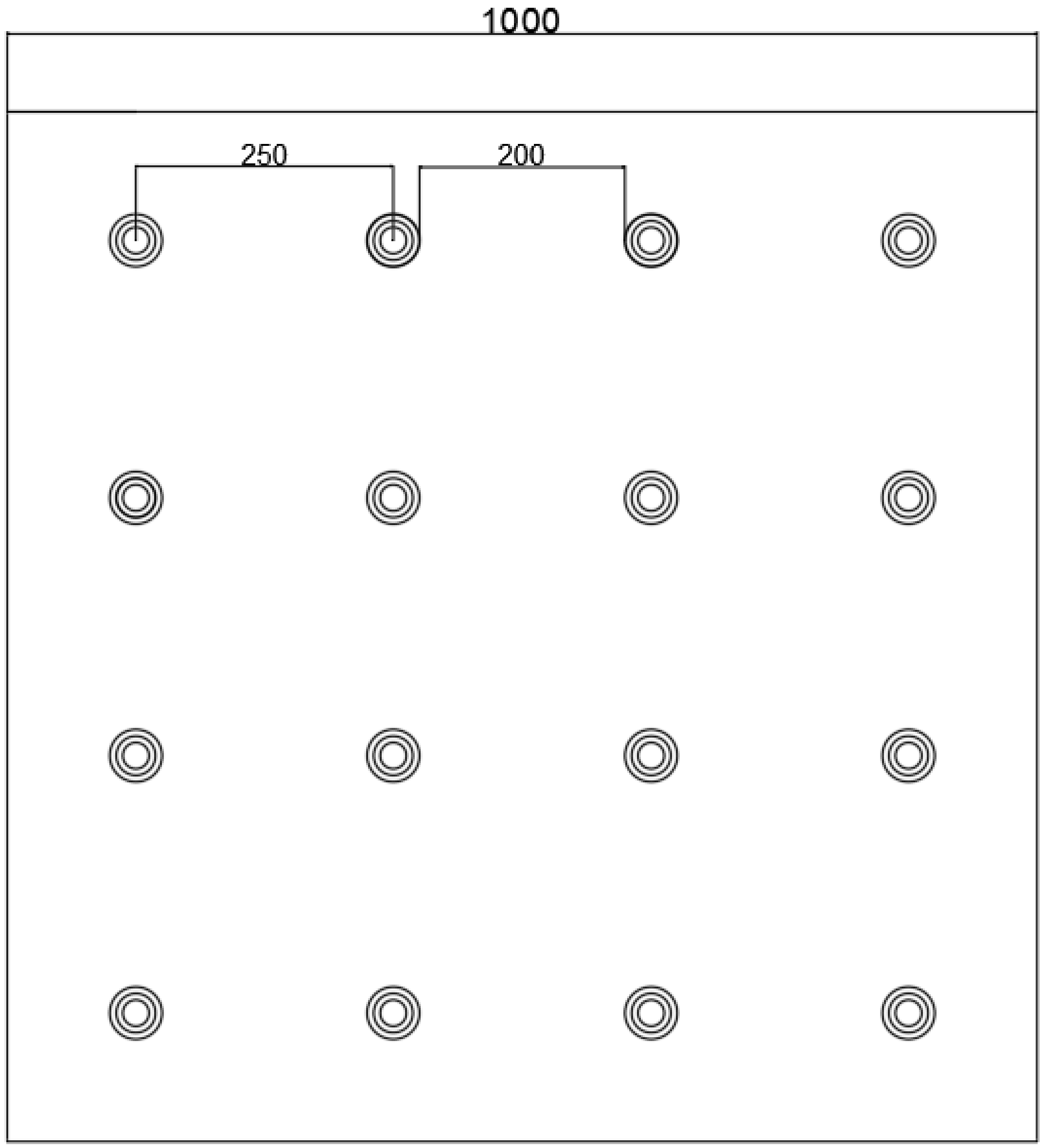

Fig. 3.5 - BTU layout on square panel

To avoid unnecessary weight on airplane by installing ball mat in cargo compartment optimal type of BTU is required. Since it is specific load on floor value the specific load on one ball is equal:

$P_{BTU} = P_a / n_{BTU} = 332,29 / 16 = 20.76\ (kg/m^2)$

3.6 Calculation for penetration a plane with a BTU ball

When a ball is pressed against a flat supporting surface, normal stresses, called contact stresses, arise in both bodies. With an increase in the compressive force, the contact stresses increase. The ball and the plane of the support body are elastically deformed. Elastic - this means that when the load is removed, the bodies will return to their original state. We will not find any holes - traces of plastic deformation. With a further increase in the compressive force and the contact stresses reaching a certain limiting value for the less solid of the bodies, an irreversible process will begin - crushing of the surface at the point of contact with the formation of a hole.

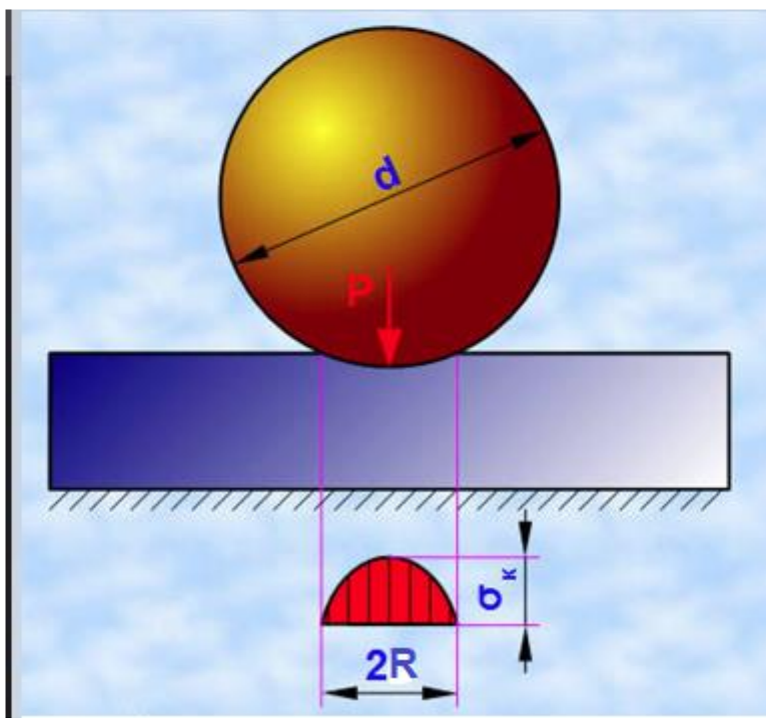

Fig. 3.6 - Scheme of ball pressure on plane

The calculation for crushing, proposed below, was performed in Excel using the formulas.

$[P_{BTU}]$ is specific load on one ball (20.76 kg/m^2 = 203.5 N/m^2);

$[\sigma_т]_B$ is yield point of the ball (1700 MPa);

$[\sigma_т]_{ULD}$ is yield poin of the ULD (235 MPa);

[E] is elasticity module (For ball is 211000 MPa; for ULD is 137293 MPa).

Radius of contact zone is calculated as:

$$R_{c.z}=0,88*(d*P/E)^{(1/3)} = 0,256 \text{ (mm)}.$$

Area of contact zone is equal:

$$A_{c.z.} = 3.14*R^2_{c.z} = 0.205 \text{ (mm}^2\text{)}.$$

As area of contact zone is calculated it is possible to evaluate limit contact stress for the ball and ULD, which stand on it. Thus, next formula is used:

$$[\sigma_к]_B = (2,571-4*R^2_{c.z.}/d)*[\sigma_т]_B = 1817 \text{ (MPa)};$$

$$[\sigma_к]_{ULD}=2,571*[\sigma_т]_{ULD} = 1101 \text{ (MPa)}.$$

From contact stress the normal stress can be calculated as follows:

$$\sigma_к=P_{BTU}/R_{c.z} = 992 \text{ (MPa)}.$$

To evaluate safety factor and prevent plastic deformation of ball or ULD lets calculate as follows:

$$k_B=[\sigma_к]_B/\sigma_к = 1.89;$$

$$k_{ULD}=[\sigma_к]_{ULD}/\sigma_к = 1.11;$$

The calculation for crushing showed that the safety factors of the contact strength are greater than one. This means that at a given load of 203.5 N, the ball has a contact strength of 89% and the support plane only 11%. The bodies will deform elastically and reversibly without reaching the plastic stages and without forming dents in the contacting areas of the surfaces.

3.7 Ball Mat Panel installation

Since it is evaluated how to ball transfer units ьmechanism are placed it is require to distribute it in structure panel. Today most efficient choice is honeycomb light weight composite structure, and it has some features.

A typical honeycomb floor panel is contain:

1. Mat Overlay which provides additional impact and wear protection.

2. Top skin. Carries loads caused by bending. Also provides impact resistance and wear protection.

3. Edge fill. Helps prevent liquid from getting into the panel structure.

4. Core. Light-weight honeycomb structure provides stiffness and strength.

5. Bottom skin. Carries loads caused by bending of the panel.

6. Vibration Dampeners. Reduce vibration and noise travelling through the panels.

Panels are made from honeycomb light weight sandwich panels with carbon – epoxy – glass faces and aramid core. Usually this panels have foam inside to prevent smoke appearance in cabin and to absorb vibrations during flight. Edge fillet prevents liquid contamination from getting into panel structure.

Floor panels can be standard or heavy-duty configurations depending on the applications. In my case I install panels in plane which has heavy big amount of unloading and loading cycles, so heavy-duty panel is the best decision in combination with chosen BTUs.

Advantages of using composite honeycomb floor panel:

- Durability
- Strength
- Stiffness
- Impact and crush-resistance
- Shear strength
- Flammability resistivity properties

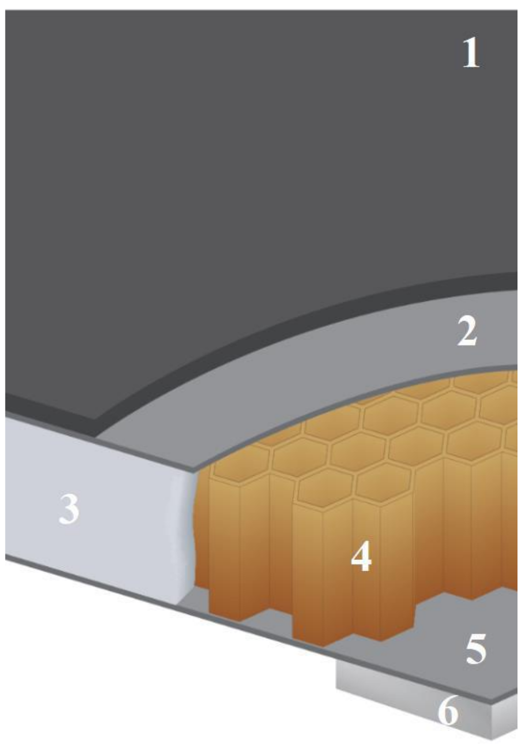

Fig. 3.7 - A typical honeycomb light weight composite floor panel

Conclusion to part 3

Main design parameters, engineering background and concept of the ball mat floor for short take off and landing aircraft cargo compartment were calculated. Optimal ball transfer unit mechanism was chosen is 6025-5-13B with given parameters by evaluated load on the ball mat. It is Hi-tech double seal ball transfer units which withstand load at 1 ball 20.76 kg/m^2 and spaced from each other 250 mm and 125 mm from each edge. Also calculation of ball and ULD penetration were done. Safety factor for BTU and ULD is more than 1, plastic deformation is absent due to cargo transportation.

Next aims were achieved:

1. Ball mat design taking into account aircraft capacity, expected loads on the floor, cargo compartment geometry where derived.
2. Maximum commercial load on each BTU were calculated, necessary quantity of BTUs were chosen.
3. Strength analysis and stress calculation of plastic deformation were performed. Safety factor were calculated.

Thus, by using a ball mat together with a composite panel floor with calculated parameters, it is possible to effectively improve the work when loading and unloading an aircraft and quickly deliver cargo faster and in greater quantities due to current realities of coronavirus.

Cargo will be loaded with power drive units and help of ball transfer units in cargo compartment. Free movement of cargo in all direction is provided. Fixed cargo will be transported and quickly unloaded due movement of ball transfer units and PDUs.

Part 4. ENVIRONMENTAL PROTECTION

4.1 Requirements towards cargo aircraft fueling

In this diploma work installation of mechanism which simplifies cargo loading / unloading is considered. Thus, ball mat floor gives opportunity to not install additional hinges, etc and that fact sufficiently improves fuel efficiency. Viewed from the side of environmental protection – better fuel efficiency tends to lower air pollution. Prototype is STOL aircraft with range of flight less than 5000 kilometers, thus fuel efficiency will be relatively high as shown in Figure 1.

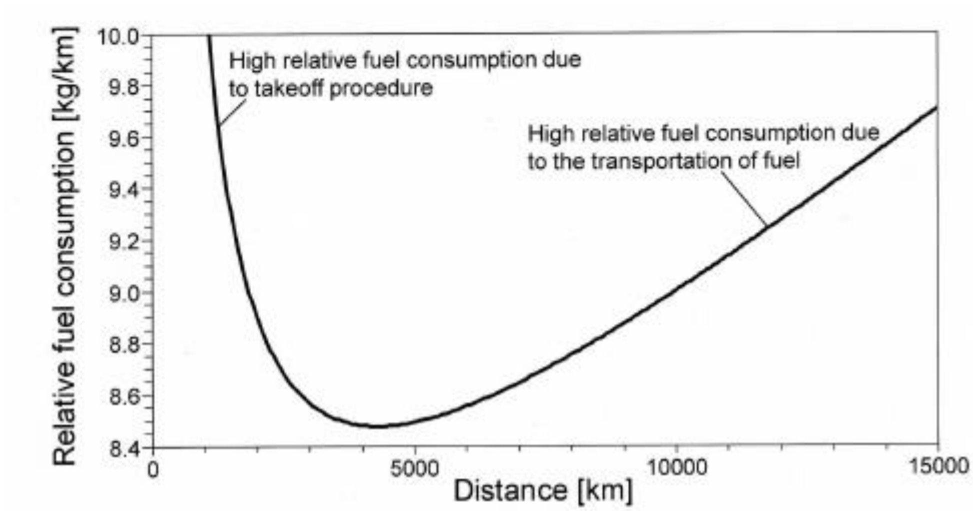

Figure 4.1.1 Relative fuel consumption diagram

Let’s consider the requirements of refueling the aircraft by The International Air Transport Association (IATA).

Aircraft refueling is carried out only with conditioned and prepared. Fuels and lubricants with provision of safety measures and prevention of losses of fuels and lubricants. Aircraft refueling sample. Each requirement must be numbered typographically and have stamp and details of the Airline. The flight engineer (mechanic, pilot, ITS) subscribes to the aircraft refueling requirement. Everything the columns of the requirement must be filled in according to their names: First copy of the completed request for refueling the aircraft, refueling is transferred. Requirements indicating the number of the control coupon are attached to the flight assignment. Organization or Airline conducts laboratory analyzes of fuels and lubricants and prepares them for documentation. Refueling the aircraft in the absence of documents for the submitted fuel and lubricants is prohibited. Aircraft refueling is carried out with the permission of an official, under whose responsibility is the sun. Persons permitting refueling and employees carrying out it bear responsibility for the quality and safety of the work performed. Aircraft refueling is carried out using centralized refueling systems or special vehicles (TZ, MZ) and other refueling facilities, in accordance with the requirements documents for their operation. Handouts serviceable and clean, filter covers and filler necks are sealed in established order. Refueling agents are allowed to be used only after their control examination.

The required amount of fuel for the flight is determined by the aircraft commander. The decision on the amount of fuel to be refueled is made taking into account its remainder in the aircraft tanks. The measurement of the remaining fuel is carried out by the flight engineer, and in the case of the transfer of the vessel to the IAS, together with the aircraft technician meeting the aircraft. On an aircraft with one crew member, the PIC measures the remaining fuel. The requirement for the actual refueling is issued by the flight engineer (pilot, ITS). A copy of the requirement for fuels and lubricants indicating the number of the control coupon is attached to the assignment on the flight.

The requirement for the fuel required for the production of maintenance is issued by the aircraft maintenance manager. After refueling, the aircraft technician responsible for releasing the aircraft into flight records in the logbook and map the amount of fuel filled and its total amount in the tanks. If after that refueling was carried out, then the amount of refueling fuel and the total amount after refueling are recorded.

The refueling specialist is obliged to ensure:

• access of refueling facilities only on command and under the supervision of a specialist in charge of the aircraft, in accordance with the approved scheme of the entrance;

• control inspection of filling facilities;

• presentation to the person under whose responsibility the aircraft is located, a control coupon for fuels and lubricants, a sample of fuels and lubricants drained from the TZ sump and obtaining permission from him to refuel the aircraft;

• grounding of the filling facility and installation of thrust blocks under its wheels,

connecting the cable for equalizing the electrical potential of the TK to the aircraft;

• docking of the nozzle of the dispensing hose with the filling connection of the aircraft with a closed filling, providing electric

(pistol) with a side socket at the neck of the tank on an aircraft with an open refueling (in the absence of a socket - before refueling, touch the dispensing valve

the plating of the vessel is not closer than 1.5 m from the neck of the tank);

• opening the necks of the fuel tanks (filling nozzles);

• pumping fuel into aircraft tanks;

• disconnecting the tip of the dispensing hose from the on-board refueling nozzle and closing the necks, nozzles after refueling.

Aircraft refueling is prohibited in the following cases:

• fuel and lubricants not corresponding to this type of aircraft were supplied for refueling;

• the inspection revealed the non-conformity of the fuel and lubricants;

• the control coupon is incorrectly executed;

• refueling means do not meet the requirements imposed on them.

• It is prohibited to refuel, refuel, drain fuel with a high level of evaporation (aviation gasoline) if there are passengers on board the aircraft.

Safety measures taken to prevent mixing of different fuels.

The list of fuels permitted for use on the aircraft is determined by the operational documentation for each type of aircraft, unless otherwise specified by the documentation, then:

- Flights of domestic aircraft using Jet A fuel (specification ASTM D 1655 USA) are prohibited.

- Flights on Jet A fuel (CAN / CGS B specification

compliance with the following conditions:

1.the proportion of TC-1 (PT) fuel in the mixture with Jet A fuel in the aircraft tanks before departure must be at least 30%;

2.the temperature of the fuel in the tanks is monitored throughout the flight and should not be below minus 40 ° C.

Before issuing a permit for refueling fuel in an aircraft, the flight engineer is obliged, according to a control coupon, to check the compliance of its brand with this type of aircraft, the content of the additive in the fuel PVK, the date and time of control of the sample drained from the TZ settling tank, the presence of signatures of officials of the organization producing the refueling or an engineer of fuels and lubricants confirming records in the control coupon.

In case of a positive result of operations, the commander of the aircraft, based on the report of the flight engineer, makes a decision on refueling the aircraft with the fuel provided.

In cases where fuel is supplied for refueling, the brand of which does not correspond to the type of aircraft or the list of foreign fuels and lubricants permitted for use, their substandard quality is revealed during the check, the control coupon is incorrectly drawn up or the refueling facilities do not meet the established requirements, refueling of the aircraft is prohibited.

For special fluids, drinking water, gases supplied for aircraft refueling (hereinafter referred to as special fluids), passports must be submitted with records of the control carried out and their compliance with the established standards.

At the same time, forms for technical means of refueling must be presented, which indicate the date of filling the product with a special liquid and control examination facilities.

The flight engineer (flight attendant) taking on board the aircraft special fluids is obliged to check their compliance with the standards.

Thus, correct fueling of cargo aircraft in pair with good fuel efficiency and cruise speed will give not bad result for environment and will decrease level of air pollution from cargo airplane.

But nowadays more and more scientific technologies give possibility to produce non-standard fuel, which emit less CO2 due to burning. Also such type of fuel is produced from sustainable feedstocks and is very similar in its chemistry to traditional fossil jet fuel. This type of fuel is called Sustainable Aviation Fuel (Figure 2) and will be considered in next section 4.2.

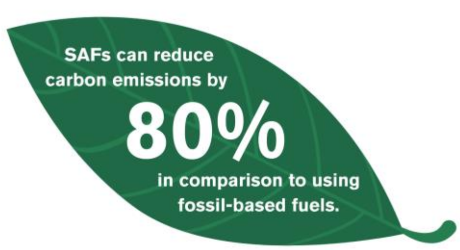

Figure 4.1.2 SAFs compared to fossil-based fuels.

4.2 Environmentally friendly aircraft fuels

As mentioned previously there is additional way to decrease air pollution – is to use environmentally friendly sustainable aviation fuel. Let’s consider more detail what is SAFs.

SAF is a turnkey solution. This means that the aircraft can be powered by the SAF without any modification. Moreover, the SAF is composed of a mixture of conventional jet fuel with unconventional, more environmentally friendly additives. Thus, it can be instantly replaced with conventional jet fuel.

Moreover, given that SAF is a relatively recent term, it is sometimes referred to by other names. For example, bioreactive fuel, bio-kerosene, alternative jet fuel, and unconventional jet fuel are all acceptable terms.Sustainable aviation fuels are made from biomass or recycled carbon. These blends meet stringent sustainability standards for land, water and energy use.Moreover, SAFs avoid direct and indirect land-use change. For example, tropical forests are not cleared for the production of SHS. In addition, SAF production does not crowd out or compete with food crops. Thus, it has a positive socio-economic impact.

Sustainable aviation fuel consists of three key elements:

1. Sustainable
2. Alternative feedstock to crude oil
3. Fuel

However, SAF follows a different path - although it shares some of the elements with conventional jet fuel, given that they are mixed together, SAF starts with raw material growth. It is then transported, processed, cleaned and blended, sent to airports, and then sent on a plane.

However, SAF production is much more cyclical. That is, the raw material used for SHS absorbs part of the carbon generated during fuel combustion.

In addition, as mentioned earlier, SAF can provide a 1.5–3% improvement in aircraft fuel efficiency.

Eco-friendly aviation fuel has grown significantly over the past seven years. In addition, this growth is expected to continue exponentially.

As seen above, about 50% of all airports around the world supplying SAF started doing so in 9 months. Hence, there is no reason to expect this to slow down.

In terms of SAF production figures, production levels in 2025 are expected to be about 17 times higher than in 2020.

Just over 59 million gallons of SAF were produced in 2020.

Based on the intentions of key SAF players, over 72 million SAF gallons are expected to be produced in 2021.

Fuel means jet fuel that meets the technical and certification requirements for use in commercial aircraft.

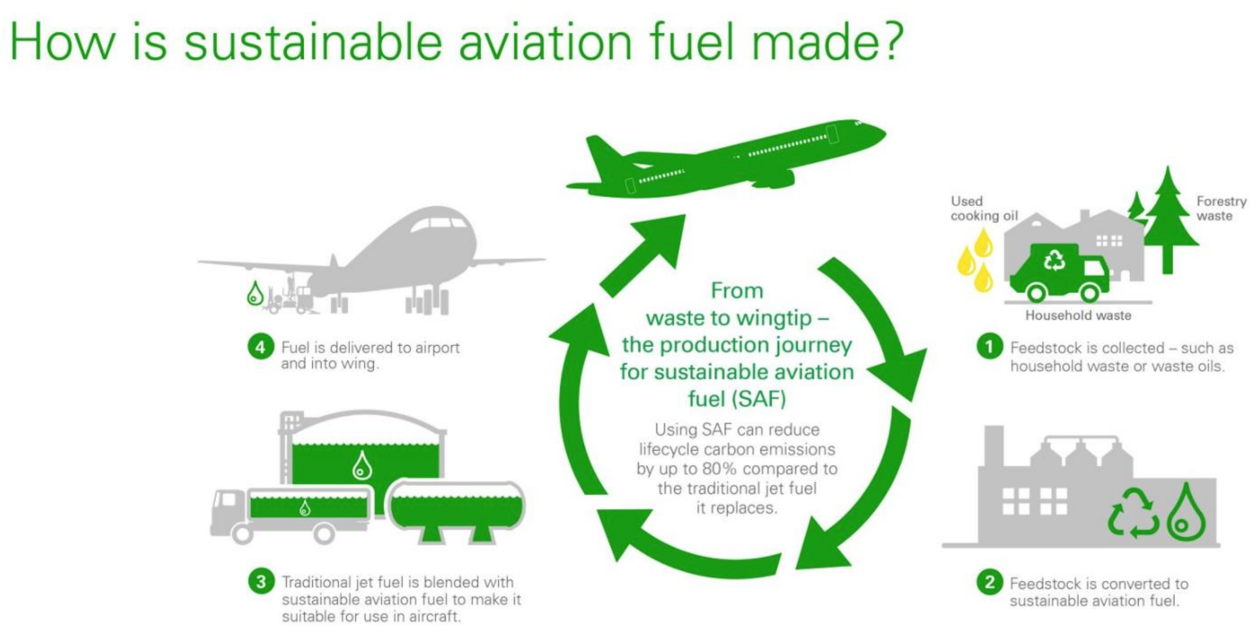

Figure 4.2.1 How is SAF made.

Jet fuel packs a lot of energy for its weight and it is this energy density that has really enabled commercial flight. Today, there aren't any other viable options for transporting groups of people quickly over very long distances. A return flight between London and San Francisco has a carbon footprint per economy ticket of nearly 1 tonne of CO2e. With the aviation industry expected to double to over 8 billion passengers by 2050.

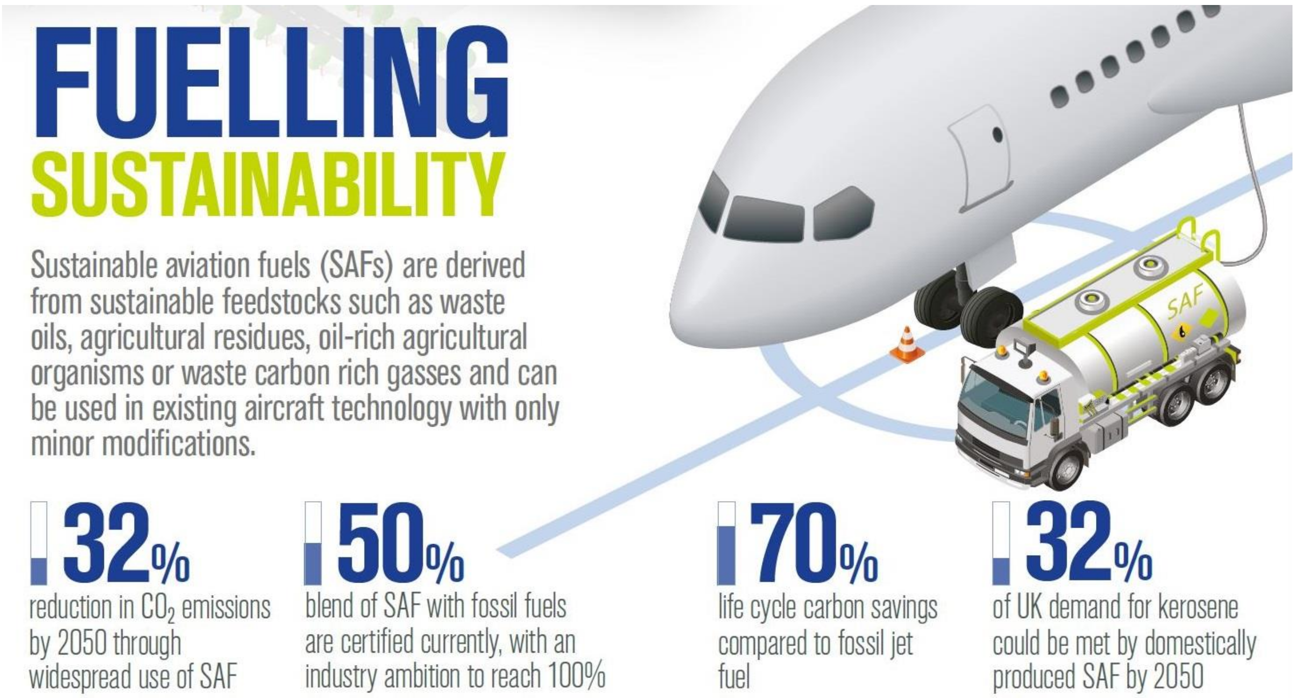

Figure 4.2.2 Fuelling sustainability

After the production of environmentally friendly aviation fuel, this is a complete solution. This means that SAF can be used in place of the regular Jet A and Jet A-1 fuels. Moreover, if the SAF meets the international standard ASTM D7566, it can be used with aircraft certified to use D1655 Jet A or Jet A-1 fuel.

SAF can be blended at up to 50% with traditional jet fuel and all quality tests are completed as per a traditional jet fuel. The blend is then re-certified as Jet A or Jet A-1. It can be handled in the same way as a traditional jet fuel, so no changes are required in the fuelling infrastructure or for an aircraft wanting to use SAF.

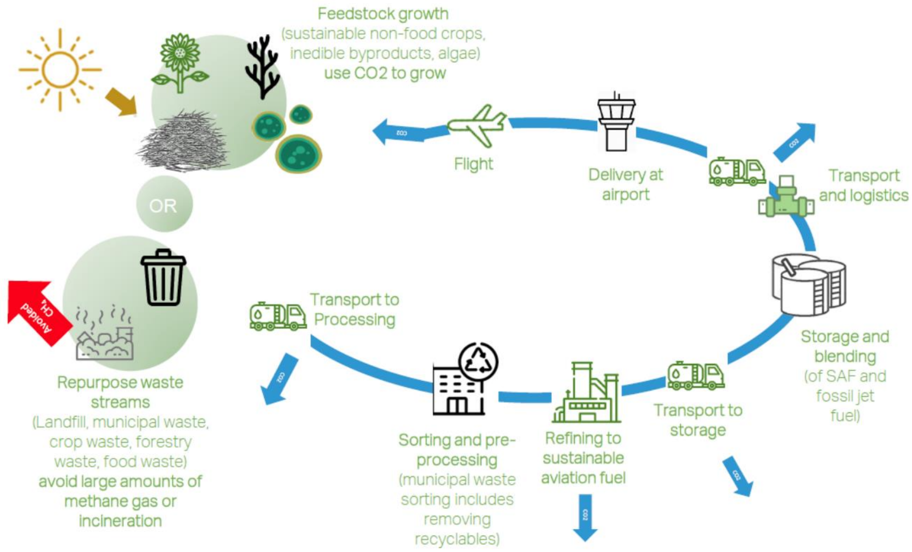

Figure 4.2.3 Carbon life-cycle diagram

In the case of SAF produced from municipal waste, the environmental gains are derived both from avoiding petroleum use and from the fact that the waste would be otherwise left to decompose in landfill sites, producing no further benefits and dangerous greenhouse gases like methane, rather than being used to power a commercial flight, which would otherwise be powered by unsustainable, fossil-based fuel.

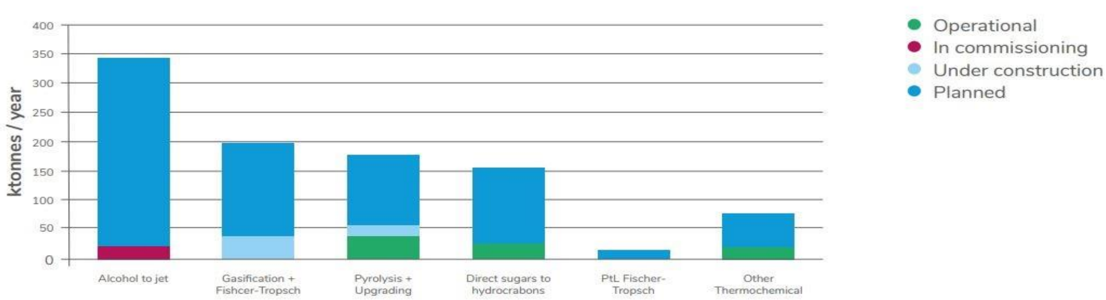

Figure 4.2.4 Plant capacities

Figure 4.2.5 shows the level of existing and potential production capacity around the world.

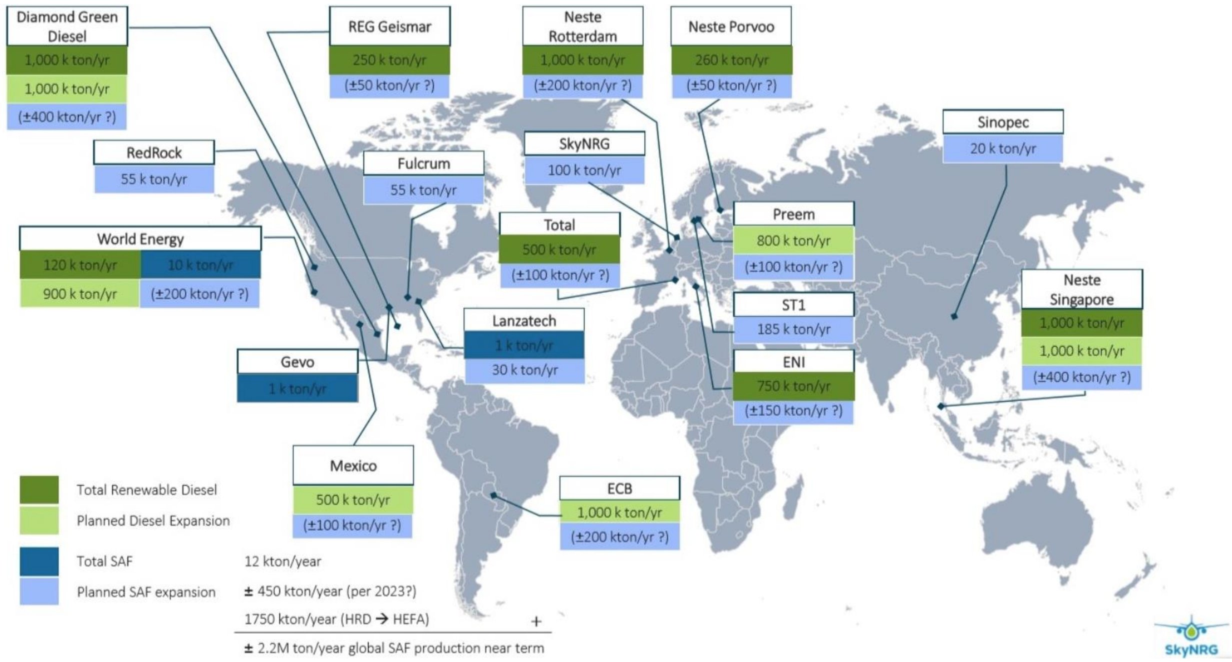

Figure 4.2.5 Existing and annouonced SAF production

Conclusion to part 4

Fuel is typically single biggest operating value for the aircraft industry. Sustainable aviation fuels are the go-to solution to help reduce aircraft emissions.Do not pretend that this will reduce emissions to zero. This is not true.However, the aviation industry is aware of aircraft emissions. Progress is accelerating rapidly, and a greener future is just around the corner.Just remember, everyone wants to burn less fuel. Less fuel not only improves environmental impact, but also leads to significant cost savings.

Therefore, it is much better to think of this biofuel as an ideal stopover. This is especially true given the rapid development of electric and hydrogen aircraft. However, the time it takes to develop, certify, and distribute means action is required now.The future belongs to electric and hydrogen aircraft. The only question is when. Considering that it will likely be 10 to 15 years before we see electric planes, SAF is the best option at the moment.

Part 5. LABOR PROTECTION

5.1 Introduction

General question of this diploma work is to improve ball mat floor of STOL (short take off and landing) cargo aircraft. Installation of such a complex construction should be carry out by educated and skilled specialists to prevent injuries and incidents during job preparation and execution. The subject of this work is an qualified engineer with approved certifications who works in hangar of STOL cargo airplane and perform the installation of ball transfer units in composite flooring. In this chapter will be considered hangar working space and conditions in which job is carry out to prevent harmful effect on someone’s health.

5.2 Analysis of working conditions

Standard hangar working conditions may be dangerous for unprepared workers. Height, concrete, spillage of fluids may result injuries and even death. Appropriate certification for ability to use special tools must be examined. Thus, all of the mechanics and personnel, which are involved in job, which is carried out in hangar, should sign document on familiarization with labor protection and safety requirements.

5.2.1 Workplace organization

A typical aviation hangar is designed to be a working place for 5 person. The total area of open space is equal to:

$$A = a * b \, [m^2],$$

$$A = 27{,}15 \text{ m} * 14{,}75 \text{ m} = 400{,}46 \text{ m}^2,$$

Where [a] is length and [b] is width (Figure 5.1)

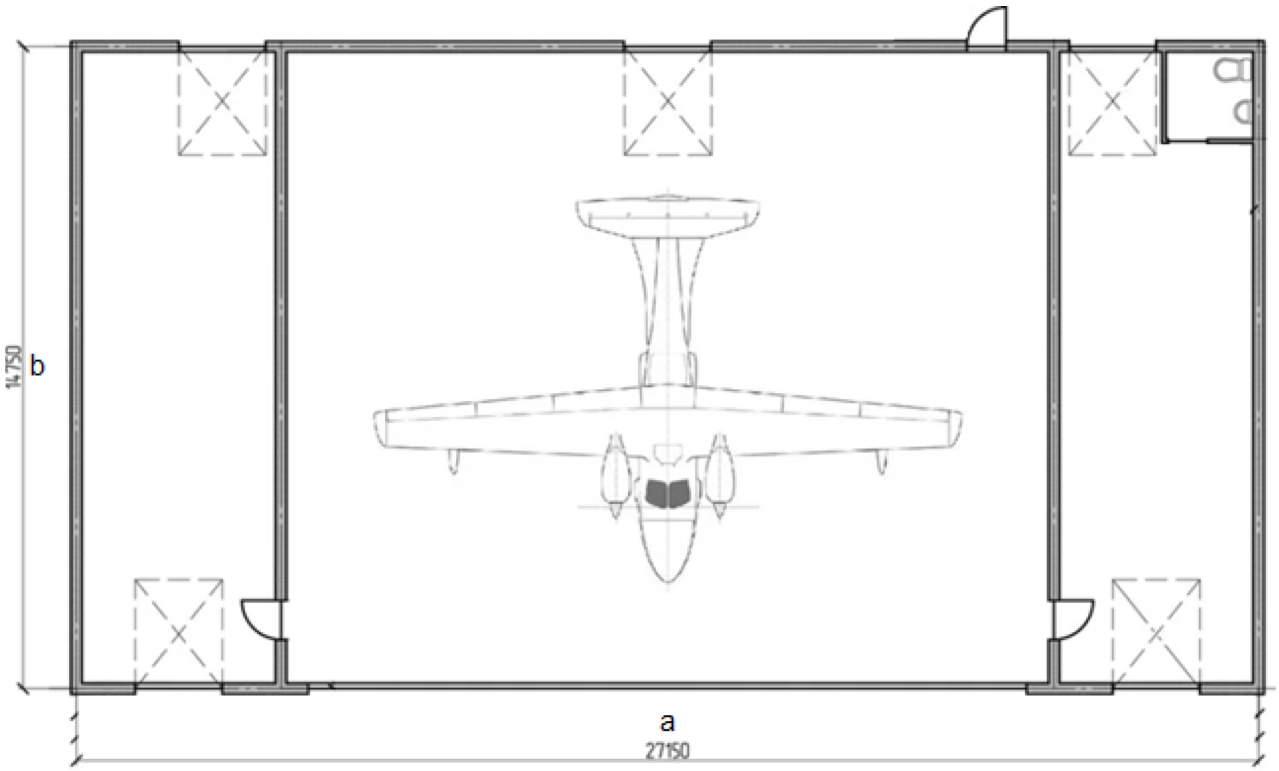

Figure 5.1 Hangar layout

Calculated working area for one person is approximately equal to:

$$A_{person} = A / n \ [m^2],$$

$$A_{person} = 400{,}46 / 5 = 80 \ m^2$$

Where [n] is number of employees.

Volume oh hangar is determined as follows:

$$V = A * h \ [m^2],$$

$$V = 400{,}46 \ m^2 * 10{,}28 \ m = 4116{,}7 \ m^3$$

Where [h] is height of the hangar.

Hangar perimeter is calculated and equal to:

$$P = 2a + 2b \text{ [m]},$$

$$P = 2 * 50 + 2 * 50 = 200 \text{ m}$$

Aviation hangar for maintenance STOL cargo aircraft meets ICAO Part-145 requirements and IATA C-25 requirements with sufficient space for maintenance and rebuilding works.

Side walls of hangar is equipped with 5 two meters length windows and 20 ceiling lights.

Temperature in hangar should be:

- Winter not less than 15°C
- Summer not more than 25°C

Relative humidity should be: 40-60%

Air velocity: 0.3 m/s

Hangar is equipped with ventilation system and air conditioning system. Also, there are several types of sockets for 180, 220 and 360 Volts. Ceiling is equipped with 2 hinges for engine removing. Typical main noise sources are tools for drilling and rivet installation tool. Also hangar is equipped with WC and 2 separate work rooms with workbenches and machine tool. First aid kit is placed in WC, 6 fire extinguishers are placed by the perimeter on the walls.

5.2.2 The list of harmful and hazardous factors

In accordance with the hygienic standards ГН від 08,04,2014 №248 «Гігієнічна класифікація праці за показниками шкідливості та небезпечності факторів виробничого процесу» we can define the list of harmful and hazardous factors:

1. Microclimate (temperature, humidity, air velocity)
2. Production noise

3. Local vibration

5.2.3 Analysis of harmful and dangerous production factors

The following factors is distinguished as:

- Protection against noise and local vibrations working with rivet tools.
- Protection against noise made from mechanical parts of aircraft such as engine, etc.
- Normalization of air temperature filtering and recirculation.
- Normalization of illumination. Comfortable condition for operations as at day time as night.

5.2.3.1 Microclimate of the working place

A microclimate can be defined as any area where the climate differs from its surrounding area. Microclimate analysis is performed by comparison of actual air condition with optimal.

Table 5.1 Microclimate characteristics comparison

	Optimal	Winter	Summer
Temperature, °C	22-24	+5	+25
Humidity, %	40-60	59	41
Air velocity, m/sec	0.1	0.3	

Table 5.1 shows that summer period of time is more comfortable for work to be done, because of optimal temperature and humidity.

During physical exertion, hypothermia of the body can cause a significant change in heart rate, impaired blood microcirculation in tissues, and a decrease in skin temperature to frostbite. Long-term work leads to a change in the immune system, a decrease in defense mechanisms, an exacerbation of not only chronic pulmonary, but also vascular diseases, endocrine diseases.

That is, the degree of cooling of the body, and, consequently, the risk of developing the disease depends on the combined effect of meteorological factors (temperature, speed of movement and relative humidity), heat-shielding properties of clothing and footwear, personal protective equipment, and the duration of the employee's stay in cold. Hypothermia of the legs is especially dangerous, which can provoke the development of many diseases: from a common cold to inflammation of the organs of the genitourinary system. It is also the most common cause of the development of cystitis, pillonephritis, tonsillitis, bronchitis.

It is very easy to get cold feet - with high humidity, hypothermia can occur even at a temperature of + 5˚C.

5.2.3.2 Production noise

Noise pollution occurs when unwanted sounds enter the environment. The potential health effects of noise pollution include increased stress levels, sleep disturbance, or hearing damage. Noise pollution is the spread of unwanted sounds into the environment.

Impact on mental health:

The brain is always monitoring sounds for signs of danger, even during sleep. As a result, frequent or loud noise can trigger anxiety or stress. With continued exposure to noise pollution, a person’s sensitivity to stress increases.

People living with noise pollution may feel irritable, on edge, frustrated, or angry. If a person feels they cannot control the amount of noise in their environment, its impact on their mental health intensifies.

Impact on physical health:

The physical health effects of noise pollution can occur as a direct or indirect result of noise exposure.

In severe cases, loud sounds can directly cause hearing impairment. Some forms of noise-induced hearing impairment include:

- abnormal loudness perception
- tinnitus, which causes a persistent high-pitched ringing in the ears
- piracies, or distorted hearing

5.2.3.3 Local vibration

There are two types of vibration:

- Whole Body Vibration (WBV)
- Hand-Arm Vibration (HAV).

Whole Body Vibration (WBV) caused by poorly designed or poorly maintained vehicles, platforms or machinery cause other health effects such as:

Lower back pain (damage to vertebrae and discs, ligaments loosened from shaking); Motion sickness; bone damage; varicose veins/heart conditions (variation in blood pressure from vibration); stomach and digestive conditions; respiratory, endocrine and metabolic changes; impairment of vision, balance or both; reproductive organ damage.

The longer a worker is exposed to WBV, the greater the risk of health effects and muscular disorders.

Hand-Arm Vibration (HAV) long term exposure from using hand held tools such as pneumatic tools (concrete breakers), chainsaws, grinders etc., causes a range of conditions and diseases, including:

White finger (also known as "dead finger") - damage to hands causing whiteness and pain in the fingers; Carpel tunnel syndrome (and other symptoms similar to occupational overuse syndrome); Sensory nerve damage; Muscle and joint damage in the hands and arms.

These conditions and diseases can have very serious consequences for people. The effects can be permanently disabling even after a few years of uncontrolled exposure.

A complete assessment of exposure to vibration requires the measurement of vibration acceleration in meters per second squared (m/s2). Health research data tells us that the degree of harm is related to the magnitude of acceleration.

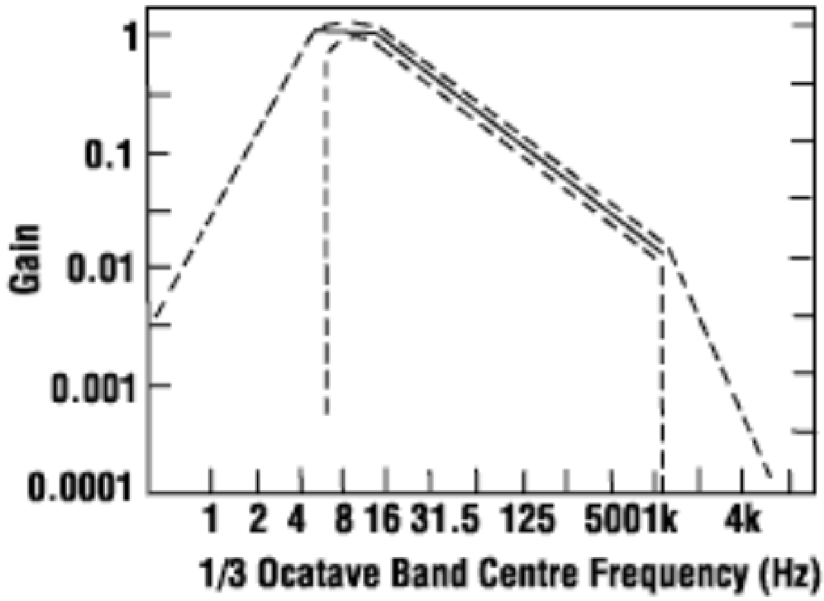

Figure 5.2

The frequency-weighting network for hand-arm vibration is given in the International Organization for Standardization (ISO) standard ISO 5349. The dashed lines in Figure 5.2 represent the filter tolerances in the weighting network.

To prevent and decrease harmful vibration effects, the following recommendations can be applied:

Use a minimum strength hand grip that still allows the safe operation of the tool or process.

Wear sufficient clothing, including gloves, to keep warm.

Avoid continuous exposure by taking rest periods.

Rest the tool on the work piece whenever practical.

5.3 Engineering, technical and organizational solutions to prevent the effect of harmful and hazardous factors due operations

- How to work in low temperature microclimate:

Due to operations in winter time workers should wear additional warm jumpsuits and jackets to prevent illness. But while working with machine tool or other dangerous apparatus performer should remember about accident prevention methods. Thus, additional rooms are equipped with heaters to warm up in it at winter time. But there is a risk of ignition, fire protection system is described in Chapter 5.4

- How to reduce noise pollution:

Repair or replace old machinery: old appliances, vehicles, and other items can be louder than newer models. Consider upgrading or replacing noisy tools. Wear special headset, that isolate environmental sound and prevent its direct influence on ears and brain. If loud noise is unavoidable, use ear protection, such as earplugs or earmuffs, to reduce its impact.

- How to prevent and decrease harmful vibration effects:

Use a minimum strength hand grip that still allows the safe operation of the tool or process.

Wear sufficient clothing, including gloves, to keep warm.

Avoid continuous exposure by taking rest periods.

Rest the tool on the work piece whenever practical.

5.4 Fire safety

Installing firefighting equipment in aircraft hangars per НАПБ А.01.001-14 «Правила пожежної безпеки в Україні» is as much about protecting the aircraft as it is the hangar itself, such is the cost differentiation between the hangar and its contents. NFPA requires that all aircraft hangers be properly equipped with fire extinguishers that can extinguish Class A and B fires (Table 5.2). These guidelines are published under the NFPA 407 Standards on Aircraft Hangers.

Table 5.2 Classification of fires

	GROUP III	GROUP II	GROUP I
Construction Type	Maximum Single Fire Area (ft2)	Maximum Single Fire Area (ft2)	Maximum Single Fire Area (ft2)
Type I (442)	30,000	40,000	Over 40,000
Type I (332)	30,000	40,000	Over 40,000
Type II (222)	20,000	40,000	Over 40,000
Type II (111)	15,000	40,000	Over 40,000
Type III (211)	15,000	40,000	Not Allowed
Type IV (2HH)	15,000	40,000	Not Allowed
Type II (000)	12,000	40,000	Not Allowed
Type III (200)	12,000	40,000	Not Allowed
Type V (111)	8,000	40,000	Not Allowed
Type V (000)	5,000	40,000	Not Allowed

For evacuation from the hangar employees should follow the emergency EXIT lights. Figure 5.3 shows emergency evacuation scheme and fire extinguisher locations.

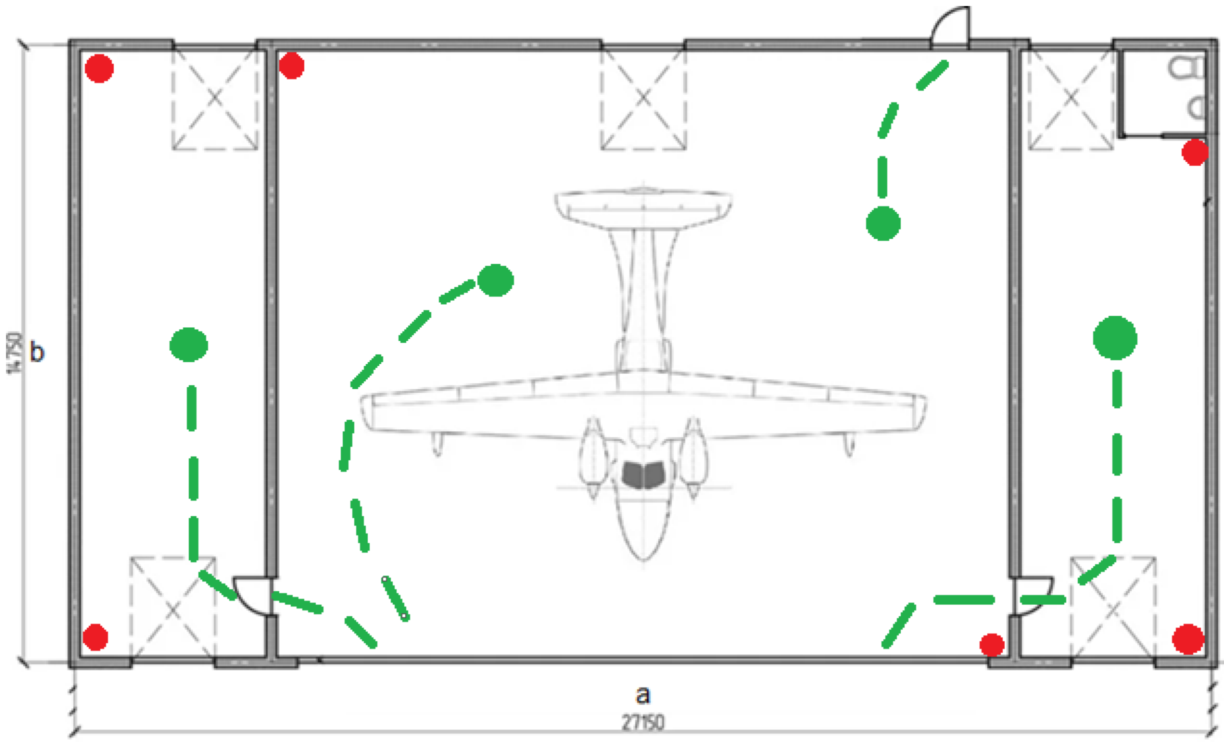

Figure 5.3 Emergency evacuation scheme

5.5 Hangar heating calculation

The internal temperature in the calculated room should be +16 degrees Celsius, the outside temperature is -34 degrees Celsius. For the construction of the load-bearing walls of the building, a 150-millimeter "sandwich" was used; mineral wool acts as a heater. It is planned to heat the hangar using the air heating technology, which will be combined with the supply ventilation installed in the workshop. This brings us needs to determine the required number of air heaters. The air exchange of the workshop is 1 time per hour, the gates are opened twice a day, the calculation data is as follows:

The heating period at the enterprise lasts 218 days. The design temperature outside the production area is -34 degrees Celsius, the average is -6.5 degrees. Over the entire heating period, the enterprise will take 160 working days. During working hours, the temperature inside the workshop should be set to +17 degrees Celsius, in non-working hours - +5 degrees.

$$Q_T = V * \Delta T * K/860$$

Where,

[QT] is the thermal load experienced by the room during working and non-working hours, measured in kW / h;

[V] is the volume of the room that needs to be heated, measured in cubic meters, calculated as the product of the length, width and height of the object;

[ΔT] is the difference between the outdoor air temperature and the indoor temperature, measured in degrees Celsius;

[K] is the coefficient of the size of the heat loss (4.5) for a specific building in which the room is located;

860 - dividing by this number allows you to convert the received heat load into kW / h, more convenient for those calculations that will be made later.

Calculation shows that the maximum hourly heat consumption during the operation of the hangar is 1098.58 kW, and during non-working hours – 361.37 kW.

Heat loss for one square meter of the floor of the room is equal to 76.1 W, for the whole object - about 340548 W.

So power of air heaters should be equal to 1098.58 kW. It will be most efficient to use 4 outdoor air heaters each have power 300 kW.

$$4 * 300 = 1200 > Q_T \text{ Winter } (1098.58 \text{ kW})$$

Conclusion to part 5

1. In this chapter the hangar where ball mat flooring is install on STOL cargo aircraft has been examinated to satisfy labor protection norms. The hangar heating system was calculated and 4 heaters should be installed.
2. The most effective method of prevention harmful effects due operation with aircraft tools is to use safety instructions and to be certified to carry out special type of operations.

References

[1] IATA: IFTP Standard Fueling Procedures

[https://www.iata.org/contentassets/828efe1a6a2a487aacaa8fe7642f0c72/iftp-standard-fueling-procedures_service-levels-and-safety-v1.00.pdf]

[2] IATA: What is SAF?

[https://www.iata.org/contentassets/d13875e9ed784f75bac90f000760e998/saf-what-is-saf.pdf]

[3] IATA: SAF - SUSTAINABILITY CONSIDERATIONS

[https://www.iata.org/contentassets/d13875e9ed784f75bac90f000760e998/saf-and-sustainability.pdf]

[4] Air BP: What is sustainable aviation fuel (SAF)?

[https://www.bp.com/en/global/air-bp/news-and-views/views/what-is-sustainable-aviation-fuel-saf-and-why-is-it-important.html]

[5] ADS Group: A Guide to Sustainable Aviation Fuels

[https://www.adsgroup.org.uk/sustainability/sustainable-aviation-fuels/]

[6] ICAO Fueling Inspections: International and FAA Fuel Fire Safety ICAO Annex 14, Chapter 9

[https://www.icao.int/NACC/Documents/Meetings/2012/ICAOFAAAGACertification2012/ICAOFAACertification14.pdf]

[7] William E. Thoms, Frank J. Dooley. Airline labor law.

[8] Protection For Employees In The Aviation Industry.

[https://teamster.org/whistleblower-protection-employees-aviation-industry/]

[9] Самолетные ангары. Пожары в ангаре и системы пожаротушения

[https://www.pnx-spb.ru/catalog/hangar/]

[10] Эмпро. Быстровозводимые ангары

[http://4094092.ru/avia]

[11] HeatingHelp

[https://forum.heatinghelp.com/discussion/158903/airplane-hangar-heating]

[12] 14 CFR Part 25 – Airworthiness standards: transport category airplanes

[https://www.law.cornell.edu/cfr/text/14/part-25]

[13] Karuskevich M. V., Maslak T.P. «Design of aviation machines. Modern regional turboprop». Lecture outline. – K.: NAU, 2007. – 60.

[14] Karuskevich M.V., Maslak T.P. «Aircraft. Design». Lectures course for the students of speciality 6.070102 «Aeronavigation». – K.:NAU, 2013. – 176 p.

[15] Попов А.В., Шпакович Н.И., Маслак Т.П. Методические рекомендации по выполнению дипломных работ (проектов) для студентов специальности 272 «Авиационный транспорт» специализации «Техническое обслуживание и ремонт воздушных судов и авиадвигателей». – К.: НАУ, 2017. – 56с.

[16] Житомирский Г.И. Конструкция самолетов: Учебник для студентов авиационных специальностей ВУЗов. – М.: Машиностроение, 1991. – 400 с.

[17] Гаража В.В. Конструкция самолетов: Учебник для студентов авиационных специальностей ВУЗов. – К.: КМУГА, 1998. – 524 с.

[18] Проектирование самолетов: учебник для вузов / под ред. С. М. Егера. – 3-е изд., перераб. и доп. – М.: Машиностроение, 1983. – 616 с.

[19] Конструкція та міцність літальних апаратів (частини 1,2): методичні рекомендації до виконання курсового проекту для студентів спеціальності 134 «Авіаційна та ракетно-космічна техніка»/уклад.: С.Р. Ігнатович, М.В. Карускевич, Т.П. Маслак, С.В. Хижняк, С.С. Юцкевич. – К.: НАУ, 2018. – 139 с