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Department of aircraft design

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MASTER THESIS
(EXPLANATORY NOTE)
OF EDUCATIONAL DEGREE
«MASTER»

EDUCATIONAL PROFESSIONAL PROGRAM
«AIRCRAFT EQUIPMENT»

Theme: «Development of elements of a system for aerial cargo delivery by the gravity method»

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NATIONAL AVIATION UNIVERSITY

Aerospace faculty
Department of aircraft design
Master's degree
Specialty 134 «Aviation and space rocket technology»
Educational professional program «Aircraft equipment»

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TASK

for the master thesis

MARYNA MYKHAILENKO

1. Theme: «Development of elements of a system for aerial cargo delivery by the gravity method», approved by Rector’s order № 1906/ст from 5.10.2020 year.
2. Period of work execution: from 5.10.2020 year to 13.12.2020 year.
3. Initial data: cruise speed V_{cr}= 620 km/h, flight range L = 1385 km, operating altitude H_{op} = 10.6 km, crew members 2, payload 15 tons.
4. Content (list of topics to be developed): analysis of problems and approaches of cargo airdrop, methodology, preliminary aircraft design as an object for research design implementation, centering determination, development of elements of container delivery system, strength calculation of the buffer stop and centers of gravity of conteiners, analysis of harmful and dangerous production factors, calculations of carbon monoxide and nitrogen oxide emission by aircraft.
5. Required materials: general view of the airplane (A1×1); layout of the airplane and containers of type A-22 and buffer stop (A1×1); assembly drawing of the buffer stop (A1×1).

Graphical materials are performed in AutoCad, NX, Excell.

6. Thesis schedule

№	Task	Execution period	Done
1	Task receiving, processing of statistical data.	5.10.2020– 10.10.2020	
2	Methodoly.	11.10.2020 – 15.10.2020	
3	Aircraft layout, centering determination.	16.10.2020 –25.10.2020	
4	Graphical design of the parts.	26.10.2020 – 8.11.2020	
5	Calculation of center of gravity of conteiners.	9.11.2020-13.11.2020	
6	Graphical design of the buffer stop and strength calculation of it.	14.11.2020 – 28.11.2020	
7	Completion of the explanation note.	29.11.2020 – 5.12.2020	

7. Special chapter consultants

Chapter	Consultants	Data, signature	
		Task issued	Task received
Labor protection	Ph.D., associate professor O.V. Konovalova		
Environmental protection	Ph.D., associate professor L.I. Pavliukh		

8. Date: “_____"___________ 202__ year.

Supervisor of diploma work __________ S.S. Yutskevich

Task for execution is given for __________ M.O. Mykhailenko

ABSTRACT

Master degree thesis «Development of elements of a system for aerial cargo delivery by the gravity method»

121 p., 35 fig., 10 tables, 17 references

Object of study – elements of a system for aerial cargo delivery by the gravity method, such as buffer stop.

Subject of study – is development of new buffer stop suitable for container delivery system.

Aim of master thesis - is to develop a new buffer stop suitable for containers of the type A-22 (48 "* 48") used for the containers delivery system and for the drop of cargo by gravity method.

Research and development methods - creation of 3D models and stress-strain analysis; - methods for collecting factual information; - theoretical research methods: analysis method; - empirical research methods: comparison method.

Novelty of the results – it is the first time designed buffer stop installation suitable for airborne transport equipment used on aircrafts that produced in our country. Buffer stop would ensure the implementation of the airdropping of cargo from aircraft in accordance with NATO standards.

Practical value – is improvement of aircraft capabilities during cargo airdropping by gravity method. Buffer stop facilitates the work of a person in the process of loading cargo on board and also to prevent abnormal emergencies during the flight and at the process of dropping cargo from the aircraft. The results of the work can be implemented in aviation airborne industry by the adaptation for empowering of airborne transport equipment.

AIRCRAFT, PRELIMINARY DESIGN, CONTAINER DELIVERY SYSTEM, BUFFER STOP, STRESS-STRAIN STATE CALCULATION.

CONTENT

INTRODUCTION

Recently, we can observe that with the technological development of mankind, the influence of these modern technologies on nature increases, which leads to an increase in the number of disasters and cataclysms. These processes entail an increase in the need for the delivery of humanitarian supplies or military equipment in the shortest possible time around the world. Frequently, the delivery of goods must be carried out in hard-to-reach areas. Therefore, when choosing the type of cargo delivery, this factor is taken into account. The most suitable method of delivery is air delivery, since this type does not depend on the natural landscape of the land and the delivery time is shorter than other types of transportation.

Delivery of cargo by air can be carried out using the airdropping method. The greatest advantage of this method among others is that this method does not require the determination of the aircraft landing zone, which is rather difficult to find during the war period or after natural disaster, and also the area of the drop zone is smaller than the aircraft landing zone.

There are various systems for dropping cargo according to altitude of airdrop. They are represented in a figure 1:

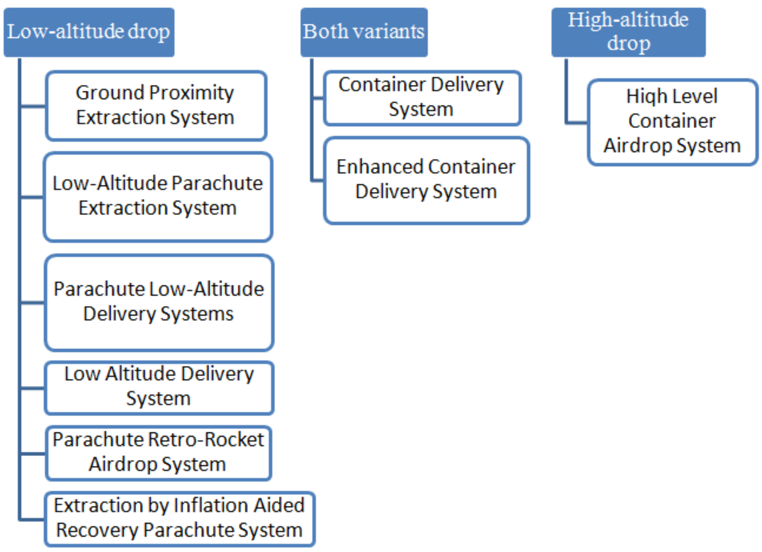

Figure 1 – Types of cargo delivery systems

But the most effective and applied and less costly dropping system is Container Delivery System, which can be used both for low and high altitudes of cargo airdrop.

Airdrop of cargo in Afghanistan began immediately with the introduction of the first American units in October 2001. As the coalition forces were drawn into hostilities and the size of the contingent of coalition forces increased, the volume of the dropped cargo increased steadily. The main method used for dropping cargo is gravity. When using it, the aircraft flies with a climb, the pitch is 7-10 degrees. Cargo parachute system leaves the aircraft's cargo compartment on rollers under the action of gravity. In total, 2005-2018 in Iraq, Afghanistan and Syria, military transport aircraft of the United States (mainly) and their allies delivered 118 198,427 tons of various cargoes by parachute landing [5].

This system is universal and can be used on any military aircraft with airborne transport equipment. But to integrate this system, it is necessary to install existing or develop new buffer stop installation on an aircraft, which are used to facilitate the work of a person in the process of loading cargo on board and also to prevent abnormal emergencies during the flight and at the process of dropping cargo from the aircraft.

There are various analogues of this buffer stop installation used on the C-130, C-17, A-400M aircrafts. An analysis of the design of these installations was carried out and the disadvantages and advantages of the installation were identified. After analyzing the structures, it can be concluded that these stops cannot be integrated under the airborne transport equipment used on aircraft manufactured in our country due to it structural features.

Therefore, it became necessary to develop a buffer stop that would ensure the implementation of the airdropping of cargo in accordance with NATO standards.

The aim of this work is to develop a new buffer stop suitable for containers of the type A-22 (48 "* 48") used for the containers delivery system and for the drop of cargo by gravity method.

To gain this aim the following objectives have been formulated:

- to analyze current trends in the airborne equipment and systems of delivery cargo;
- to investigate actual buffer stop installations and detection of their advantages and disadvantages;

- to propose improved design of buffer stop suitable for airborne equipment used on aircrafts produced in our country;
- to determine methods of aim achievement – creation of 3D models and stress-strain analysis; - methods for collecting factual information; - theoretical research methods: analysis method; - empirical research methods: comparison method.
- to engage preliminary design procedure of aircraft for development of the research object;
- to select primary parameters for designed aircraft;
- to estimate geometrical parameters of the wing, tail unit, fuselage, landing gear, etc.;
- to estimate range of center of gravity locations.

Also it was designed buffer stop installation for container delivery system, with dimensions 1200×1219.2×800 mm, withstands the load of 10 containers of cargo weight of 1102 kgf.

As an example of the aircraft for the implementation of the new buffer stop the flight range L = 1385 km, payload 15 tons, take-off mass 54665 kg aircraft is considered. The preliminary design of the plane includes: analysis of the similar planes, selection of the geometrical and mass characteristics of the planes, calculation of new plane parameters with emphasis on the centering of the aircraft.

Problems related to labor and environmental protection in the modern community are very relevant, therefore special attention was paid to the given problems in the corresponding parts of the diploma work.

In the part «Labor protection» some aspects of hazardous and harmful production factors affected on the design engineer during process of performing work, main requirements to the workplace of engineer and proposed measures to reduce this hazardous affect on engineer are described.

In the part «Environmental protection» was considered impact of aircraft on the atmosphere by determining the level of its pollution due to the emission of harmful substances from the exhaust gases of aircraft engines, calculated emissions of CO and NO_x from aircraft engine and proposed methods to it decreasing.

1 ANALYSIS OF PROBLEMS AND APPROACHES OF CARGO AIRDROP

In the life of modern humanity occupy an increasingly prominent place worries related to overcoming the crisis, including the catastrophic situations of different nature, emergency management, first of all natural, man-made, environmental and military nature, for which today characterized by a high degree of risk. It is also necessary to take into account the influence of time on the course of events when delivering important humanitarian and military supplies during military operations. Many countries are engaged in developments to improve methods of delivery of goods, reduce delivery times and make them cheaper.

1.1 Types of ways for cargo transportation

There are 4 main types of cargo transportation in the world: cargo transportation by air - air transportation, cargo transportation by water, and cargo transportation by land, they in turn are divided into two types - road transportation and railway transportation.

The transportation of various cargoes, goods in all centuries of mankind was one of the main types of economic relations between countries and peoples. In parallel with the development of technical progress, cargo transportation also developed, modern technologies and devices were introduced, including aircraft. Cargo transportation by air is quite popular nowadays, because it has advantages over other types.

1.2 Main factors affecting on the choice of type of cargo delivery

Consider the factors affecting the choice of delivery of military and humanitarian cargo by aircraft:

Delivery speed. The speed of delivery of goods by air cannot be compared with any other known type of delivery. There are cargoes that need to be transported over fairly long distances in a minimum amount of time (perishable food, various valuables, organs for transplantation and military equipment).

It does not depend on the complexity of the geographical landscape. Often, air transportation is used when you need to transport cargo through a territory with a difficult landscape, for example, through a mountain range, or to remote corners of the world where there are no roads and there is no other means of transport to get there.

Reliability. Robbing or stealing at a height is a rather difficult task, so additional escort costs are not needed.

The control. It is very easy to track the location of the aircraft and the cargo inside it by attaching a conventional sensor with a GPS signal to it and tracking it via satellite. Also, there is minimal customs control, you do not need to go through inspection in all states that the plane crossed the airspace.

1.3 Advatages and disadvantages of air transportation and airdrop

The main advantages of air cargo transportation are as follows:

– delivery of goods is done very quickly (several times faster than by water or land transport);

– the best protection of goods, they are almost not exposed to possible problems (in this way it is optimal to transport dangerous and expensive goods);

– delivery to almost anywhere in the world (especially to those places where it is impossible to get by other transport).

Along with the positive aspects, there are also disadvantages of air transportation:

– the cost of air transportation is very high (they are the most expensive method of transportation);

– oversized cargo is difficult to transport by air, it is better to do it by water transport;

– the absence of an airport makes it impossible to deliver goods.

It is necessary to take into account the fact that the military actions are not always in areas where there are airports or railways and roads, so use dropping cargo in war zones, which minimizes the possibility of delivering the goods in some other way.

The material and technical support of troops in areas of combat operations, in which there are no prepared take-off and landing sites, has always been and still is a serious problem. For many years, a number of methods have been used to deliver cargo by air, including conventional parachute landing, as well as landing of assault forces. Each of these methods was associated with solving its own problems, such as preparing landing sites for cargo or aircraft landing, performing time-consuming operations to load cargo and stowing parachute systems, or reducing the loads on the aircraft structure during landing.

Problems associated with the landing operations, maneuvering the aircraft on the ground and unloading it on unprepared runways can significantly limit the coverage area of a combat operation, as well as reduce the resource and service life of the aircraft.

Aerial delivery is the air transport of cargo, equipment and/or personnel to a desired location on the ground by aircraft. These aircraft include military, contracted, and commercial as well as strategic and theater fixed-wing airlift. Aerial delivery also includes the use of rotary-wing as transportation platforms to move personnel, equipment, and sustainment supplies [3].

Airdrop systems have a mix of delivery capabilities to support operations ranging from wide-area free drop distribution to low altitude ballistic parachute drops to high altitude GPS-guided systems with substantial stand-off capability. Factors including standard considerations: the mission, enemy, troops, terrain and weather, troops and support available, time available, civil considerations; and supplies and cargo to be delivered determine the system and type of aircraft used for the delivery [3].

Consider advantages of airdrop:

- can be used when no other means for transporting supplies or equipment is available;
- reduces the need for forward airfields, reducing the battlefield footprint;
- permits greater dispersion of ground tactical forces;
- reduces in-transit time and handling requirements from the source of supply to the ultimate user;
- airdrop, as opposed to airland, enables a shorter turnaround time for non-landing aircraft, and reduces risks to the aircraft, increasing aircraft availability, and survivability;
- provides a key advantage in forcible entry operations.

Disadvantages of airdrop include:

- aircraft remains vulnerable to enemy air defense systems based on drop level;
- allows no backhaul capability;

– creates a need to recover and retrograde aerial delivery equipment unless low cost expendable equipment is utilized;

– the net payload is reduced because of the relatively heavy weight of the airdrop rigging equipment;

– requires specially trained army rigging personnel and flight crews;

– airdrop drop zones must be secured to prevent supplies from falling into enemy hands;

– remains dependent on favorable weather conditions;

– airdrop operations require an extensive planning effort and much longer cycle times;

– increased requirement for rigging materials and special aerial delivery equipment.

1.4 Aerial delivery equipment classification

Aerial delivery equipment is applied to materials, devices, hardware, and other items used to prepare loads for airdrop. The availability of aerial delivery equipment is limited.

Aerial delivery equipment can be divided into three major classifications:

1. Rigging items, which include airdrop containers, platform and platform assemblies, cushioning and energy-dissipating materials, and other supplies and equipment used to prepare loads for airdrop. Specific items are cargo slings, airdrop bags, and platform assemblies [3].

2. Parachute assemblies include personnel and cargo parachutes. The principal personnel parachutes are the T-11, MC-6, and RA-1 worn by paratroopers for static line and military free-fall operations. The main cargo parachutes are the G-12E used singly for loads up to 2,200 pounds or clustered in pairs for loads up to 3,500 pounds, and the G-11B/C used singly for loads up to 5,000 pounds or in clusters for airdrop loads weighing up to 40,000 pounds. There are also extraction and pilot parachutes [3].

3. Equipment repair items include parachute packing and inspection tables, parachute line separators, parachute packing weights, fans and other specialized tooling [3].

1.5 Types and methods of airdrop

Let`s consider three standard types and methods of airdrop. The types are freedrop, high-velocity, and low-velocity. Airdrop types are categorized based on the load's rate of descent. The methods of airdrop are mechanized, extraction by parachute, gravitational. Airdrop methods pertain to how loads exit the aircraft. These types and methods often utilize common components and systems [3].

Freedrop is the type of delivery of cargo such, as items of equipment, which are airdropped from aircraft with low speed of flight and at low altitude of flight. This type of airdrop is performed without parachute systems. Honeycomb is used for energy dissipation during contact of cargo with ground, decrease impact of shock force on cargo.

High-velocity airdrop is type of airdrop of cargo from aircraft at high altitudes of flight and with set velocity of flight permissible for cargo drop. This type of airdrop is performed with using parachute systems for decreasing rapid rate of descent of cargo. Honeycomb is used for energy dissipation and decreasing effect of the ground impact on cargo.

Low-velocity drop is a procedure in which the drop velocity is less than 28 feet per second. Low velocity is the preferred method to drop all supplies and equipment certified for airdrop. Loads are specially prepared for airdrop either by packing the items in airdrop containers or by lashing them to airdrop platforms. Multiple parachutes can be used to achieve the desired rate of descent. Many of the Army's light and medium tactical wheeled vehicle fleet along with repair parts and major assemblies can be delivered using this method [3].

There are several methods of release of cargo:

The mechanized method is used to drop various cargoes from the cargo hatch in parachute containers or standard packages. In this case, the aircraft is equipped with a special conveyor, on the cargo chains of the highways of which cargo is placed and secured. The separation of cargo from the aircraft occurs due to the rotation of the conveyor cargo chains by an electric drive. When approaching the cut of the cargo hatch, the cargo is freed from the mooring straps of the attachment and is freely separated.

The parachute system is deployed using an exhaust parachute link attached to the aircraft's airborne cable. For the dropping of large loads of tracked and wheeled vehicles, as well as weapons and cargo on platforms and parachute-jet systems, the method of extraction cargo from the aircraft fuselage is used, when the process of dropping cargo occurs using extraction parachute systems. In this case, the cargo, moored on the platforms, is loaded onto the aircraft on a conveyor or roller equipment, and the exhaust parachute system is installed on a special fastening lock in the aircraft hatch hole. The extraction method involves the use of an extraction parachute to pull the load out the rear ramp of the aircraft cargo compartment. It is used for large low-velocity loads. This method is used for such items as artillery pieces, vehicles, special-purpose equipment, bulk ammunition and supplies rigged on airdrop platforms.

After opening the cargo hatch, by pressing the load release button, the exhaust parachute system moves away from the aircraft and is put into operation. Once completed, the exhaust canopy releases the platform mounts and pulls it out of the aircraft fuselage.

The gravitational method is used when dropping cargo from an aircraft flying with a climb at an angle of 45 °. The load under the action of gravity along the conveyor or roller conveyor equipment freely leaves the aircraft fuselage.

Thus, the task of airborne cargo is solved when the airborne equipment of the aircraft and the paratroopers work together.

1.6 Problems and approaches of airborne landing of military equipment and cargo

In order to study in more detail the problems of airborne landing of military equipment and cargo, it is necessary to analyze the history of the emergence of airborne landing systems, their purpose and their modernization throughout the development of aircraft construction.

During the Great Patriotic War, to supply troops and partisan detachments, they resorted to parachute-free dropping from low altitudes of cargo that could withstand large shock overloads, supplementing their standard packing with minimal amortization. An instruction on parachute-free dropping of cargo was issued and distributed to units of the Air Force. Small arms ammunition, hand grenades (without fuses) could be dropped in boxes wrapped in burlap, explosives in boxes - in bags with hay, soft cargo (camouflage means, uniforms) - in standard packaging. Parachute-free dropping in amortized containers of equipment, food, some samples of small arms, liquids, building materials was practiced abroad [1].

Again, work on parachute-free dropping of cargo unfolded in the 1960s, and, in addition to supply cargo, it again turned to the landing of combat, transport and special vehicles. The often used term "parachute-free" is not entirely accurate - parachutes could be used to retrieve cargo from the carrier aircraft and to brake, but not to reduce vertical speed. The flight altitude of a military transport aircraft is considered extremely low when the distance between the wheels of the extended landing gear and the surface of the landing area is about 3-5 m or even less.

In the United States, development work on low-altitude landing systems began in the early 1960s. The tactical advantage of this method was considered to be a significant increase in the accuracy of the landing and a decrease in the vulnerability of the aircraft at low altitudes for air defense systems. Firms “Lockheed” and “All American Engineering” have created and tested an airborne landing system that resembles the method of landing aircraft on the deck of an aircraft carrier using an aerofinisher. At the same time, the military transport aircraft with the extended landing gear lowered to the height of the "shaving" flight and, with an open ramp of the cargo compartment, released a cable with a hook at the end. The hook grabbed the cable of the aerofinisher, which was previously deployed across the plane's flight path. The platform, equipped with shock absorption, was removed from the aircraft, and falling onto the surface of the landing pad, slid until it extinguished its horizontal speed. On a hard-surfaced site, the platform slipped about 30 m, on friable ground - less, but at the same time braking created large overloads on the dropped cargo [1].

Already in the early 1960s, in this way, loads weighing up to 4500 kg (army truck) and rubber fuel tanks with a capacity of 2000 liters were dropped from the C-130 aircraft from altitudes up to 10.5 m at a flight speed of about 185 km / h [1].

The modified cargo landing system was designated GPES (Ground Proximity Extraction System - the extraction system when approaching the ground). According to the plan, the aircraft entered the landing site at a altitude of about 15 m, opened the doors and the cargo hatch ramp, from where a folding rod with a hook connected by a cable to the loaded platform was released using a hydraulic drive. The aircraft descended to 2-3 m slightly in front of the cable lying across and stopped the descent after catching the cable with a hook. The hook pulled the aerofinisher cable connected to two hydraulic ground braking devices. The platform with the load was removed from the aircraft, the impact energy was extinguished by a shock absorber with a paper-honeycomb filling. The hydraulic brakes have been designed so that the braking force remains constant despite the decrease in the horizontal platform speed. Its disadvantages included the need to select a flat area with the ability to fly a military transport aircraft at an extremely low altitude, a significant amount of work on the deployment of ground equipment and accurate flight control with signals from the ground. The crew of the aircraft had to withstand the altitude, direction and speed of flight, like the pilots of carrier-based aircraft.

Another way for landing from extremely low altitudes was based on the method of disruption with an extraction parachute. Basically, the method was used to drop cargo from C-130 aircraft, although there was also an option for the C-7A. The system, developed in 1964, received the designation LAPES (Low-Altitude Parachute Extraction System - low-altitude system with an extraction parachute). Since 1966, it has been used in Vietnam to deliver building materials, metal mats for the construction of field airfields, etc. The results were considered good. In general, this method had the same disadvantages as GPES, except that the preparation of the landing site took less time (the GPES system was also used in Vietnam, but much less often). A control group was pre-landed in the landing area, which set markers along the border of the site, and smoke bombs served to indicate the direction of the wind to the aircraft crews. The required size of the landing site is at least 230x45 m.

Airdrop from aircraft of the C-130 "Hercules" type was carried out by single platforms or groups (series) connected in tandem. When the aircraft approached the landing site at an altitude of 60-90 m, the crew at a certain frontier would release the landing gear and descend to a height of 1.5-3 m, maintaining a flight speed of 210 km / h. At the estimated time, the cargo hatch was opened and the stabilizing parachute was dropped. It provided the deployment of the extraction parachutes, the force of which opened the lock of the platform fastening, equipped with a shock absorption system, and the platform was removed from the aircraft. The platform exited the aircraft with a small positive angle of attack (the leading edge was raised in the direction of flight). After the loading platform touched the ground, braking due to friction and the action of extraction parachute occurred at a distance of about 60 m. Air or paper-honeycomb cushioning was used.

It is worth noting that the Americans preferred dropping systems from extremely low altitudes for large loads, although the landing of loads weighing up to 18120 kg on parachute platforms with multi-dome systems was fully worked out. Parachute landing was considered less suitable due to the "difficulty of ensuring the operation of parachute systems" when landing large loads. It is true that the system LAPES several times led to accidents even in Vietnam [1].

The USA also developed the PLADS system (Parachute Low-Altitude Delivery Systems - low-altitude parachute airdrop system). It was designed to drop cargo on a platform from a height of about 60 m using a parachute system that was quickly deployed.

Taking into account the experience of previous years of the evolution of airborne equipment, foreign experts believe that in order to create and improve modern airborne equipment, a deeper study of the factors affecting the landing process is necessary. It is believed that to solve this problem, it is advisable to use telemetry equipment used in space programs. Over the past ten years, parachute systems have been so improved that the use of outdated telemetry equipment for testing them is no longer effective. It is believed, in particular, that in order to improve the accuracy of the airdropping of heavy loads (15-30 tons) and reduce the time of their descent, data on the forces acting on the cargo at each stage of the landing process are needed: when leaving the cargo compartment, free fall, stabilization, braking, braking before landing and landing. A special need for modern telemetry means is associated with the tests of new parachutes for special forces taking place at Fort Bragg, North Carolina.

The Container Delivery System (CDS) is designed for parachute dropping of up to 16 A-22 containers with a total weight of 225 - 1000 kg from C-130 and C-141 aircraft.

The containers can be ejected one at a time or in pairs. The CDS system includes a container and a parachute system. In the cargo compartment of the aircraft, A-22 containers are installed in two rows, usually in groups of four. The airdropping accuracy is quite high - from a height of 180 m at a speed of 210 km / h 16 containers can be dropped onto a platform measuring 115x35 m. This system is one of the most frequently used for the aerial supply of highly mobile airborne troops.

A-Series containers are positioned so the cargo parachute faces inside the aircraft. All dimensions are measured in relation to how the A-Series container stands in the paratroop door. The maximum dimensions of A-Series containers are as follows: 30 inches wide, 66 inches high and 48 inches deep, to include the cargo parachute [4].

During the Vietnam war, riggers improved upon the innovations developed during the Korean conflict. Developments included the delayed opening of parachutes and the Adverse Weather Aerial Delivery System. This system greatly improved the C-130 aircraft's airdrop capabilities and accuracy in darkness or bad weather. Today, aircrews view poor weather and visibility as aids because poor conditions no longer severely affect accurate delivery of supplies, but provide concealment from small arms fire [4].

From the Vietnam war to current operations, personnel have configured CDS in the following way: a skid board constructed of 3/4-inch plywood and energy-dissipating material (cardboard "honeycomb"), an A22 container to rig equipment no taller than 83 inches, one cargo parachute, one pilot parachute, and various expendable supplies [4].

Improving airdrop accuracy and reducing costs are the goals of the Enhanced Container Delivery System (ECDS). The ECDS was initiated to improve existing Container Delivery Systems (CDS). The ECDS will be used to airdrop multiple supply containers (bundles) accurately from fixed wing cargo aircraft from 500 to 25,000 feet depending on the threat and environmental conditions. The ECDS is used to air resupply deployed Army U.S. and allied ground forces and may be used for Special Operation Forces [4].

ECDS provides the capability to air deliver multiple supply containers (weighing from 501 pounds up to 2,200 pounds) accurately from aircraft flying at low, medium, and high altitudes. Delivery altitudes are determined by the threat that delivery aircraft must counter. The ECDS is capable of 10,000 pounds per system and is not restricted to airdrop from 1100 feet above ground level, as are current CDS. ECDS will use a 463L compatible pallet that is forkliftable and slingloadable [4].

The ECDS improves the existing CDS. It uses a 463L-based platform that is easier to transport and rig. The ECDS can be moved by forklift and transported by various means. Capacity increases from the current 2,200 pounds to 10,000 pounds. Increasing the capacity reduces the number of bundles. This has a positive impact on accuracy at multiple altitudes. The disadvantage for ECDS is cost. One system's cost is estimated at $10,000, and the ECDS is not reusable based on the current design of 463L pallets [4].

The airdrop system on APS platforms (Airdrop Platform System) allows for the dropping of various types of cargo, since platforms (also called pallets) impose less stringent restrictions on the height and rate of release compared to containers. In addition, the platform is a supporting structure when transporting goods and supplying them to the hatch when ejected, and also serve as a damper when hitting the ground. The platforms are modular and assembled from sections 1.22x2.64 m in size and 6.67 cm thick, which are made of balsa wood with top and bottom panels of aluminum alloy. For fastening loads on platforms, aluminum guides with a length of 2.44 are installed at their ends; 3.65; 4.53; 6.1 or 7.32 m. The APS system, in addition to the platform, includes a extraction, one or more main and brake parachutes.

The Low Altitude Delivery System (LADS) provides dropping on unprepared limited-area cargo weighing up to 6800 kg from a height of 200 m. that required when using a standard parachute (340 m), with a simultaneous increase in the maximum load on the parachute from 1590 to 2270 kg. Modified parachutes are used in conjunction with standard cargo platforms.

To expand the possibilities of airdropping from low altitudes, two more systems have been developed and are being tested: PRADS (Parachute Retro-Rocket Airdrop System) with brake missile units and EXIARP (Extraction by Inflation Aided Recovery Parachute System), in which to reveal the main parachutes are used auxiliary.

The high-altitude container airdrop system HLCAD (Hiqh Level Container Airdrop System) provides simultaneous landing of several containers weighing 680 - 1000 kg from a height of 600 - 7600 m. Airdropping accuracy (circular probable deviation) from a height of 3000 m is 200 m.

The command of the coalition armed forces, under the general leadership of the United States, to support the actions of its units and subunits, as well as allies in Afghanistan, Iraq and Syria, widely uses parachute landing of cargo. Material assets and ammunition are actively delivered by air and dropped on cargo parachute systems. The same method is used when delivering humanitarian supplies to the local population in remote or inaccessible areas of these countries.

In total, 2005-2018 in Iraq, Afghanistan and Syria, military transport aircraft of the United States (mainly) and their allies delivered 118 198,427 tons of various cargoes by parachute landing. The list includes: ammunition, uniforms, food rations, water, fuels and lubricants, spare parts for equipment, building materials, etc. Theoretically, this would require to make sorties (by type of aircraft): 2955 - C-17, 4925 - C-130J and 7388 - C-130E / H with full load. In practice, at least three times more air sorties were carried out [5].

Firstly, the departures are not always carried out with a full load. This was due to the range and flight profile, especially when dropping cargo in mountainous areas. For example, the typical load of the C-17 aircraft was 32-34 cargo parachute systems [5].

Secondly, the parachute landing of cargo was also carried out by the C-27J, C-160, MV-22B, C-23B, CASA-212, DHC-4 aircraft, which have a lower load. The latter two types of aircraft were used by private companies under outsourcing agreements. Sometimes the landing of cargo was carried out by heavy transport helicopters such as CH-53 and CH-47 [5].

Thirdly, the flight weight of the cargo parachute system was not always the calculated 1000 kg. The mass of the dropped loads varied from 50 to 1000 kg. For example, the mass of the often used cargo parachute system for dropping four 208-liter barrels of fuel was just over 800 kg [5].

Airdrop of cargo in Afghanistan began immediately with the introduction of the first American units in October 2001. As the coalition forces were drawn into hostilities and the size of the contingent of coalition forces increased, the volume of the dropped cargo increased steadily.

The main method used for dropping cargo is gravity. When using it, the aircraft flies with a climb, the pitch is 7-10 degrees. Cargo parachute system leaves the aircraft's cargo compartment on rollers under the action of gravity. Heavy equipment was dropped by parachute disruption. From light military transport aircraft and helicopters, the manual pushing method was used by accompanying persons.

In individual cases, weapons and equipment were dropped. The heaviest single cargo parachuted was the 155 mm M198 howitzer weighing about 9.55 tons and the forklift weighing about 5.62 tons in Afghanistan [5].

The main interspecific guidance document for parachute dropping of cargo in the US Armed Forces is the Air Transportation Manual (JP-3-17, Air Mobility Operations), published by the Committee of the Chiefs of Staff of the US Armed Forces. The supply of units and subunits operating in isolation from supply bases and places of permanent deployment is always a problem.

Based on these documents, in the opinion of the US Armed Forces command, in comparison with the traditional method - the delivery of goods by land or air landing method or on external sling nodes - the method of parachute dropping of goods has a number of advantages:

- the efficiency of cargo delivery is significantly increased in comparison with delivery by land transport;
- the logistic "shoulder" is reduced, as the number of intermediate storage and distribution bases of goods is reduced;
- there is no need for aircraft landing and unloading;
- the likelihood of incapacitation of the equipment of transport convoys and losses among personnel, as well as shelling of helicopters and aircraft when delivering goods by landing method, decreases. According to the calculations of American specialists, one C-130 aircraft, landing seven cargo parachute systems weighing 1000 kg each, replaces a column of 10 vehicles with 23 servicemen, including security vehicles and security personnel;

- cargo can be dropped almost anywhere, including inaccessible for ground vehicles or where landing of helicopters (aircraft) is impossible, for example, due to weather conditions;
- forward operating bases and outposts can be located in places where there are no roads for their supply (in 2011, about 60 bases and outposts with 27 thousand troops in Afghanistan were supplied only by air).

At the same time, the disadvantages of this method are also noted:

- when dropping cargo from low altitudes, aircraft become more vulnerable to enemy air defense systems, as well as fire from small arms;
- the need to select and return containers, parachute systems for their recovery and preparation for subsequent use;
- dependence of weather conditions;
- the need to deploy specially trained ASG handlers and military transport aviation crews to the theater of operations;
- parachute landing of cargo requires careful planning and longer preparation time;
- the need to ensure the safety of landing sites for cargo in order to exclude them from falling into the hands of the enemy.

The war in the Persian Gulf confirmed the views of the military leadership of the leading countries of the world on the role and place of highly mobile airborne troops in modern warfare, made it possible to practically test the capabilities of the rapid deployment forces while performing the tasks assigned to this specific contingent of troops in real combat conditions. Skillful use of the highly mobile airborne troops potential in most cases depends on the availability of the latest airborne means of personnel, weapons, military equipment and cargo, provides real backgrounds for achieving success in confrontation with the enemy in any theaters of military operations. Modern military conflicts have shown the urgent need to create fundamentally new means of airborne assault. The appearance of inexpensive and mobile portable anti-aircraft missile systems makes it almost impossible to fly at altitudes less than 7 km, due to the danger of losing the aircraft. Along with this, the existing airborne assault means, for high accuracy, require the release of personnel, weapons, military equipment and cargo at altitudes less than 1 km. During dropping from high altitudes, delivery accuracy is usually low. This can be confirmed by the delivery of goods by parachute method to the troops that were cordoned off in eastern Ukraine during the anti-terrorist operation. Taking into account modern conceptual approaches regarding possible options for the use of the Armed Forces of Ukraine, it is the issues of the development and modernization of aerial delivery equipment for highly mobile airborne troops that become important and urgent.

Scientists abroad have been studying in more detail the problems of the development of methods for parachute dropping of weapons and military equipment of subunits and units of highly mobile airborne troops, the development and modernization of airdrop equipment in modern warfare.

These issues are covered in the most detail in the scientific works of Russian and American scientists and practitioners: Bulgakov V.V., Vorobiev I.M., Kisilev V.A., Eduarad Dousot. At the same time, as the analysis of the results of research carried out during command-and-staff exercises with military command and control bodies and troops shows, the level of effectiveness of the use of units of highly mobile airborne troops does not allow for guaranteed missions during an operation.

This situation is a consequence of the inconsistency in the development of methods for parachute drop of weapons and military equipment of subunits and units of highly mobile airborne troops with the existing means of airdrop. The development and modernization of airdrop equipment in the modern Armed Forces of Ukraine is practically not carried out, or it is carried out at the level of scientific and practical research without their further adoption by units and subunits of highly mobile airborne troops. This makes the process of using highly mobile airborne troops ineffective. Changes in the conditions for the use of airborne assault forces determine the need for a critical revision of existing approaches to the further development of the entire system of airdrop support for units and subunits of highly mobile airborne forces.

Conclusion to the part 1

In this part it was carried out the analysis of the types of ways for cargo transportation, main factors affecting on the choice of type of cargo delivery. It was chosen air transportation as way of cargo delivery due to it benefits, such as short time of delivery, sufficient reliability and protection of goods. Then it was analyzed classification of types and methods of airdrop, considered problems and approaches of cargo airdrop during development of methods for parachute drop of weapons and military equipment of subunits and units of highly mobile airborne troops. So it was identified the main problems of cargo airdrop such as cost of equipment of delivery systems and difficulties with its operation. So it was chosen gravity method and container delivery system as main way of cargo airdrop due to it cheap cost and effectiveness in use, simple construction, sufficient protection of goods from environmental and physical influence. Also using of such delivery system does not depend on the complexity of the geographical landscape which is so important factor in our days, because usually military actions take place in hard-to-reach places.

2 COMPARATIVE ANALISIS OF BUFFER STOP PROTOTYPES

2.1 Study area

The area of study of this thesis is the elements of an aerial delivery system for the release of cargo by the gravity method for an aircraft with a maximum weight of a single cargo dropped 6400 kg. The elements of the system, which will be investigated in this work, include a buffer stop, containers of the A-22 type.

The first object of the thesis is a buffer stop. This installation is used on aircrafts according to aircraft technical description:

C-130, C-17, C-295, C-27j, A-400M, C-2, KC-390, C-141, C-160, Y-20.

Due to the lack of information on all aircrafts, the work will consider analyze of buffer stoppers installed on C-130, C-17, A-400M.

2.2 Scientific methods

In this thesis, the following scientific methods are used to collect and process information:

- Methods for collecting factual information;
- Theoretical research methods (consider models of any processes and phenomena):
- Analysis is a research method characterized by the selection and study of individual parts of the research objects.
- Empirical research methods (they are based on experience or experiment):
- Comparison is a method of comparing objects in order to identify similarities or differences between them.

2.3 Analyses of prototypes structure

2.3.1 Buffer stop of C-130

This invention relates generally to an aircraft cargo system. More particularly, the present invention relates to a buffer stop assembly for use in an aircraft cargo system [10].

The aerial delivery of supplies to a ground based area is well known. Often the container delivery system (CDS) is used to accomplish such aerial deliveries. The container delivery system comprises an aircraft configured to include an aerial delivery rail system that include floor having parallel forward to aft rails, parallel rows of forward to aft rollers and a center channel there between. The side rails, rollers and center channel extend from a door in the aft section of the aircraft toward the front [10].

The supplies are enclosed within a net or “container” that is attached to a folded parachute canopy. The container and canopy are attached to a base or skid board. Each base with attached container and canopy is loaded into the aircraft and slid forward on the rollers. The first container moves forward to contact a forward stop. Each subsequent container moves forward to contact the preceding container. Each container is secured to the aircraft to prevent shifting during flight. During use the aircraft flies to a desired drop off point. The aircraft aft section door is opened, each container restraint is loosened and the containers are moved rearward on the rails to gravity exit from the aircraft. Once outside the aircraft, the canopy deploys and the container descends to the ground [10].

ACDS container can weigh up to 2,328 pounds and some aircraft can hold a total of 16 containers for a maximum cargo load of 37,248 pounds. The forward stop must prevent this load from shifting forward during flight to prevent damage to the aircraft and injury to the flight crew. It should be noted that the forward stop must be capable of preventing forward movement of the entire container cargo even when the cargo is under an acceleration of three times the force of gravity [10].

The invention in a preferred form is a buffer stop assembly for use as a forward stop in an aircraft. The inventive buffer stop assembly can be used without requiring changes to aircraft presently configured for the container delivery system. The buffer stop assembly comprises a horizontal member preferably including a type V aerial delivery panel extrusion having a side rail, strut support, and end member mounted to each side and roller pads mounted to the lower surface. The side rails and roller pads are configured and positioned to interact with existing rails, rollers and center channel of the aircraft aerial delivery rail system [10].

A vertical member preferably including a second type V-panel extrusion is arranged substantially vertically and perpendicularly to the horizontal panel. The vertical member comprises an end member and sidepiece mounted to each side of the panel. Each sidepiece is connected by a hinge block and a compression member to a respective horizontal member side rail. A plurality of inclined struts joins the perpendicular panels into a rigid assembly. A center strap bisects each planar face of the vertical panel and extends beyond the vertical panel lower edge. The center strap extending portions are mounted to an L-shaped junction [10].

The Buffer Stop is designed to secure and support heavy and bulky loads with a total weight of about 16895 kg and a weight of 27200.

The design of the stop also changes depending on the weight of the load. So, for a load weighing 16895 kg, the stop has 6 struts (Figure 2.1). For a load weighing 27,200 kg, there are already 10 struts (Figure 2.2).

Figure 2.1 - Buffer stop for a load weighing 16895 kg [12]

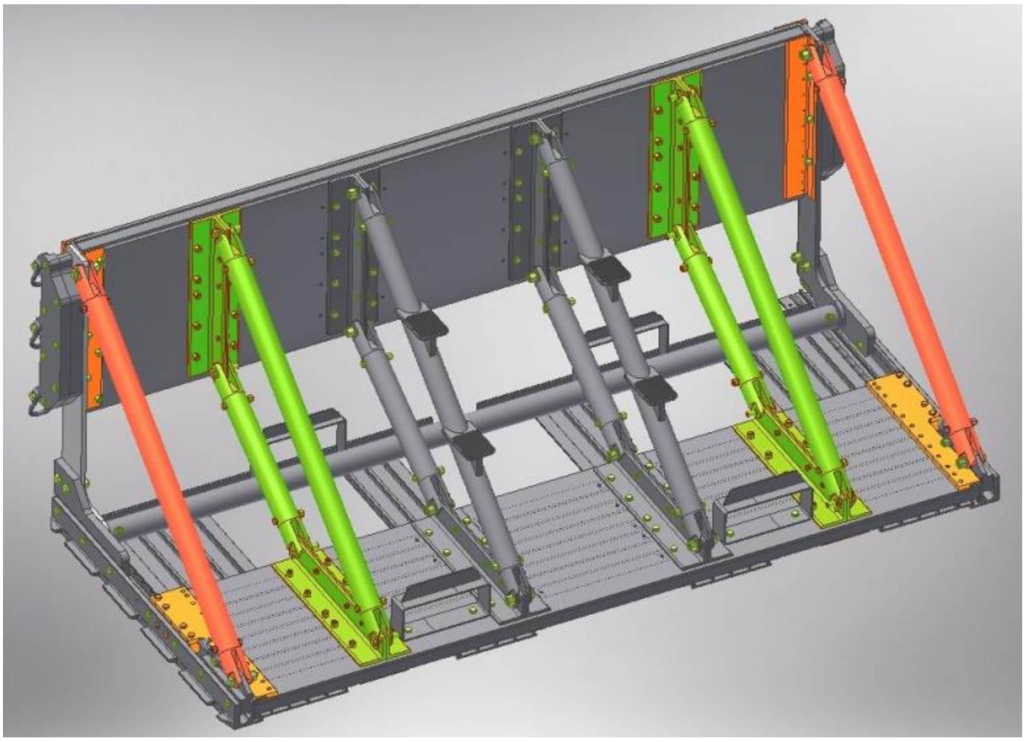

Figure 2.2 - Buffer stop for a load weighing 27,200 kg

Advantages of buffer stop installed on C-130:

- easy in operation;
- time of assembly / disassembly;
- relative compactness when folded;
- ability to install anywhere on roller equipment;
- lack of special instructions for disassembly and assembly.

Disadvantages of buffer stop installed on C-130:

- the need to use a special or fork loader for assembly and disassembly;
- not able to place in the stowed position on board;
- the size of construction.

2.3.2 Buffer stop of A-400M

The A400M aircraft is equipped with two buffer stops. The first stop is designed to hold the load on the ramp, with the possibility of dropping the load during horizontal flight. The second stop is located in the aircraft fuselage and is designed to hold the maximum weight of the load.

Accordingly, it is an object of the present disclosure to provide a simple and at the same time fail-safe cargo restraint mechanism that allows for easy handling and improved stowage of the system components. According to one aspect of the present disclosure, a cargo restraining assembly is configured to be mounted to a cargo deck surface of an aircraft. The cargo restraining assembly comprises two guidance and restraint bars running in parallel to each other, and at least one lateral bracket spanning between the two guidance and restraint bars and being fixedly connected to each of two guidance and restraint bars. The lateral bracket includes a bracket foot formed integrally with the lateral bracket and a quick release mechanism configured to quick-releasably couple the bracker foot to a seat track profile of the cargo deck surface of the aircraft. According to another aspect of the present disclosure, a cargo loading system comprises a plurality of cargo restraining assemblies, wherein the guidance and restraint bars of adjacent cargo restraining assemblies are connected to each other by a bar link and wherein the plurality of cargo restraining assemblies form a rail channel running substantially in the middle of the cargo hold from aft to fore of the aircraft [11].

According to yet another aspect of the present disclosure, an aircraft comprises a cargo hold having a cargo loading system according to the present disclosure. One idea of the present disclosure is to design a center guidance and vertical restraint channel in the middle of a cargo hold of an aircraft. The center guidance and vertical restraint channel is made up from cargo restraining assemblies which provide guidance in x-direction (from aft to fore of the aircraft) on one hand, and restraint of loaded pallets and cargo containers in y-direction (perpendicular to the X-direction on the cargo deck surface) and z-direction (normal to the plane of extension of the cargo deck surface) on the other hand. The cargo restraining assemblies are suited to be mounted to existing seat track profiles in the floor of the cargo hold by quick-release mechanisms so that the whole center guidance and vertical restraint channel may be assembled and disassembled quickly without the need for complex tools or manpower. Each of the cargo restraining assemblies has little weight so that it can be carried by a single person [11].

The buffer stop thrust mount is part of the A-400M aircraft equipment. The unit is moved along the cargo compartment of the aircraft using roller equipment. The fixation of the platform in the aircraft is carried out with the help of special chains, slings and with the help of locks of roller equipment. The design of the installation is designed so that during horizontal flight, the load is dropped by the gravitational method. Therefore, the load itself is placed on the platform at an angle of 30 °. The unit consists of an upper platform raised by 30 ° above the guide rails, secured by struts. To keep the load on the upper platform, there is a net of slings attached to a rectangular structure. Loading and unloading of the installation from the aircraft is carried out using a loader.

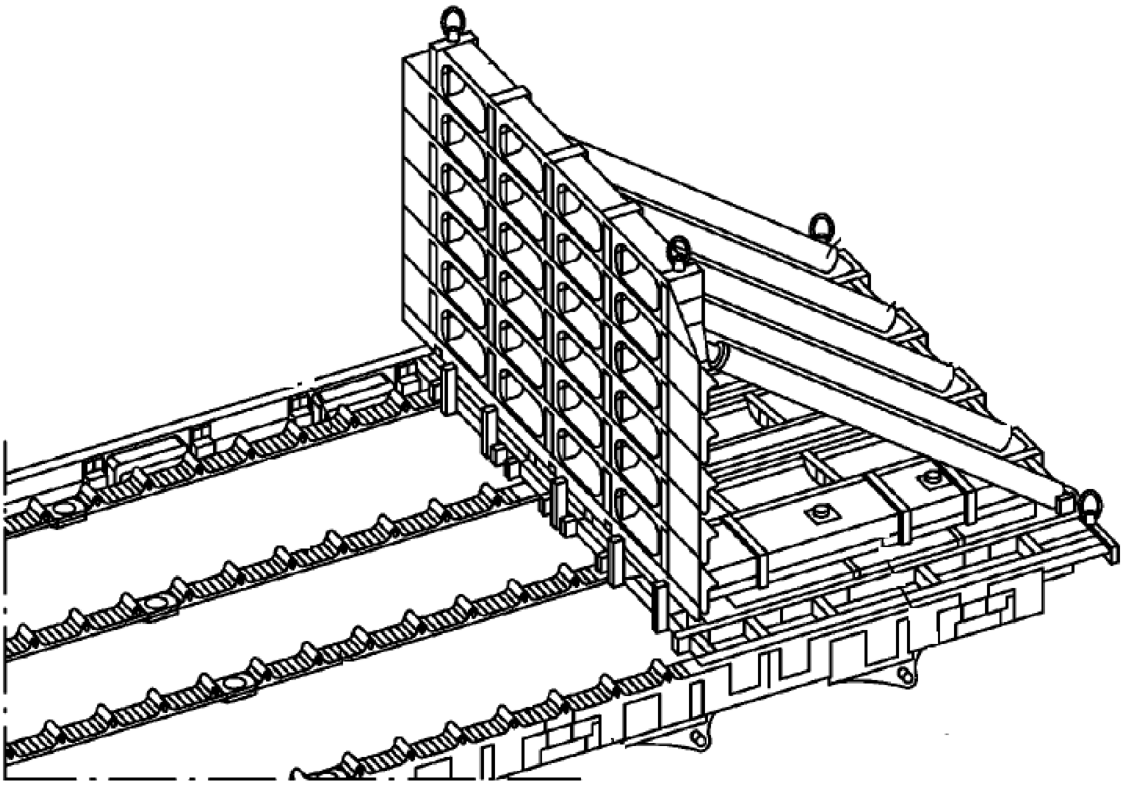

Figure 2.3 - Buffer stop installation on A-400M [11]

Advantages of buffer stop installed on A-400M:

- easy in operation;
- time of assembly / disassembly;
- lack of special instructions for disassembly and assembly.

Disadvantages of buffer stop installed on A-400M:

- the need to use a special or fork loader for assembly and disassembly;
- not able to place in the stowed position on board;
- the size of construction.

2.3.3 Buffer stop on C-17

Buffer Stop is designed to hold a load with a total mass of 56245 kg and a mass of 76 650 kg on 108in platforms. The Buffer Stop thrust mount is part of the C-17 aircraft equipment. The unit is moved along the cargo compartment of the aircraft in a raised state above the floor, using manual force. This installation is collapsible, installation and dismantling is carried out using additional tools and fasteners. The platform is fixed in the aircraft using special chains or slings. And also additional fixation to the floor with bolts or wrenches is possible. Loading and unloading of the installation is carried out by manual force (involvement of service personnel). The unit is designed in the form of a grid of square profiles.

Advantages of buffer stop installed on C-17:

- compactness of installation;
- the ability to place in the stowed position;
- mobility.

Disadvantages of buffer stop installed on C-17:

- multi-component assembly;
- requires additional floor binding equipment;
- installation / dismantling time;
- using an additional tool;
- accommodation on the plane.

Figure 2.4 - Buffer stop installation on C-17 [13]

2.4 Requirements to aerial delivery equipment

The aircraft must be provided with space for placing the entire complex of airborne transport equipment in the stowed position. At the same time, the placement of the main complex and the most frequently used equipment of the auxiliary complex should not lead to a decrease in the useful dimensions of the cargo compartment. The attachment points (suspension, etc.) of the entire complex of airborne transport equipment must be designed for the joint operation of both complexes.

Cargo cabins of the aircraft and the airborne transport equipment installed in them must provide:

- convenient and quick embarkation (loading), placement and disembarkation (unloading) of the personnel in standard equipment with personal weapons, weapons and military equipment and cargo;
- reliable individual fixation of the personnel on the seats and reliable fastening of weapons and military equipment, and cargo in the cargo compartment, taking into account the overloads that meet the current strength standards
- quick re-equipment of the cargo compartment for the use of the aircraft in various versions, provided for by the tactical and technical tasks for the aircraft, by the crew in the airfield (field) conditions
- safe parachute landing of airborne personnel in standard equipment with personal weapons with all types of parachutes in supply, weapons and military equipment with combat crews and cargo from aircraft

2.5 Requirements to equipment for dropping airborne weapons and military equipment and cargo

Equipment for dropping airborne weapons and military equipment and cargo should provide:

- reliable and safe release of the airdrop equipment with a total mass equal to the mass of the airdrop load of the aircraft;
- the same for all airborne equipment set and installation scheme, regardless of where they are installed in the cargo compartment;
- reliable fastening of the airdrop equipment in all flight modes;

– remote control of the release in the main mode from the navigator's workplace, in emergency mode - from the navigator's and crew commander's workplace;

– visual control of the correctness and reliability of the attachment of the airdrop equipment and extraction parachutes.

Conclusion to the part 2

In this part it was determined study area, chosen scientific methods used for collection and processing information. Also it was carried out analyze of structure of existing buffer stops and described advantages and disadvantages of buffer stops installed on aircrafts C-130, A-400M, C-17 and defined it significance of use in procedure of cargo airdrop by gravity method.

This buffer stop is a necessary element for the airdrop and transportation of goods in containers A-22. It facilitates the work of a person in the process of loading cargo, is an element of the airborne transport equipment and increases the level of safety during transportation. This t buffer stop will be unique for the aircrafts manufactured in our country, and will allow airdropping cargo according to North Atlantic Treaty Organization standards. Therefore, it is supposed to design installation that would satisfy the needs of aviation and was included in the list of elements of transport equipment for the modern military aircrafts produced in our country.

3 PRELIMINARY AIRCRAFT DESIGN AS AN OBJECT FOR RESEARCH DESIGN IMPLEMENTATION

3.1 Choise of the projected data

The selecting of the optimum design parameters of the aircraft is the multidimensional optimization task, aimed at forming a "look" promising aircraft. In its configuration mean the whole complex flight-technical, weight, geometrical, aerodynamic and economic characteristics. In forming the "Appearance of the plane" in the first stage is widely used statistics methods transfers, approximate aerodynamic and statistical dependence. The second stage uses a full aerodynamic calculation; aircraft specified formulas of aggregates weight calculations, experimental data.

Prototypes of the aircraft, taking for the designing aircraft were in ranges of maximum payloud of 10 to 26 tones of cargo. Such aircraft like An-178, An-74, KC-390 will compete with projected aircraft in this market segment. Statistic data of prototypes are presented in table 3.1.

Table 3.1 - Operational-technical data of prototypes

Parameters	Planes		
	An-178	An-74	KC-390
1	2	3	4
Max payload, kg	18000	10000	26000
Crew, [persons]	2-3	3-4	2
Flight range with $G_{payload,max}$, [km]	1350	1450	4850
Range of cruising altitudes, [km]	10	10.1	10.9
Number of engines and their type	2 Turbojet	2 Turbojet	2 Turbojet
Take off thrust, [kN]	2*94	2*65	2*139.4
Pressure ratio	26	20	36
Take off run distance, [m]		600	

Ending of table 3.1

1	2	3	4
Wing span, [m]	30,32	31,89	35,06
Sweepback angle at ¼ of the chord, [°]	25		
Wing aspect ratio	9,33		
Wing taper ratio	4,61		
Fuselage length, [m]	32,235	28,07	33,91
Fuselage diameter, [m]	3,9	2,5	
Fuselage fineness ratio	7,68		
Cargo cabin width, [m]	2,7	2,1	
Cargo cabin length, [m]	13,21	11,3	
Cabin height, [m]	2,73	1,8	
Horizontal tail span, [m]	9,4		
Horizontal tail sweepback angle, °	32		
Vertical tail sweepback angle, [°]	40		
Landing gear base, [m]	11,37		
Landing run distance, [m]		450	
Take off gross mass, [kg]	51000	32000	81000
Landing mass, [kg]	51000		

The high-profile scheme is determined by the relative position of the aircraft units, their numbers and shape. Aerodynamic and operational characteristics of the aircraft depends on the aircraft layout and aerodynamic scheme of the aircraft. Fortunately chosen scheme allows to increase the safety and economic efficiency of the aircraft.

3.2 Brief description of the main parts of the aircraft

The aircraft is a free-carrying high-wing aircraft with two bypass turbojet engines located in nacelles under the wing, and a tricycle landing gear with a single-strut front support and two two-strut supports.

3.2.1 Wing

The wing is swept, high-wing, with large elongation, trapezoidal in plan with a back sag, and is based on supercritical profiles.

The wing consists of a central part (center section) and two cantilever parts connected to the center section by flange joints. The wing is attached to the fuselage by four nodes and through arcs on the 1st and 2nd spars of the center section, as well as by means of a power fairing of the fuselage.

The wing design is of a caisson type. The center section caissons and the cantilever part of the wing contain spars, ribs and panels made of aluminum alloys. In the caissons there are fuel tanks, for maintenance of which hatches are made on the panels of the center section on top, and on the cantilever part of the wing – on bottom.

The wing center section consists of a rectangular caisson, nose and tail sections. The bows of the center section are installed in front of the 1st spar. For the 2nd spar, the tail sections of the center section are installed. They have retractable single-slot composite flaps. The cantilever parts of the wing are trapezoidal in plan, they include a power frame, nose and tail sections. At the ends of the cantilever wing there are trapezoidal end aerodynamic surfaces.

In the nose section of the wing cantilever there is a deflectable nose and three sections of the slat made of aluminum alloys. The nose section of the wing console part consists of panels made of composite materials and a frame made of aluminum alloys.

In the tail section of the wing console, there are two sections of retractable double-slotted flaps with a fixed deflector, an aileron and five sections of deflectable spoilers operating in braking, glide slope and aileron modes. The tail section of the cantilever wing consists of panels made of composite materials and a frame made of aluminum alloys.

3.2.2 Pylons

On both cantilever parts of the wing, two pylons are installed, to which nacelles and bypass turbojet engines are attached.

The pylon consists of a caisson, a nose part, a tail part, fairings and an assembly compartment. Inside the caisson there are pipelines and air bleed units in the air conditioning system and an anti-icing system.

On the caisson there are nodes for docking with the wing and engine attachment. The nose and tail sections, nacelle fairing, fairings and assembly compartment are attached to the caisson.

3.2.3 Fuselage

The fuselage is a thin-walled frame shell of a cylindrical shape in the middle part and a conical, double curvature shape in the nose and aft parts (compartments). In the forward part of the fuselage there is a crew cabin, and in the nose, middle and tail parts between frames 8 and 43 - a transport one.

The cockpit and transport cabin are sealed. The fuselage frame is made of semi-finished aluminum products and includes a skin, a stringer set of extruded and bent profiles, rims of standard frames, power and reinforced frames, beams and underlays for reinforcing cutouts in the shell under the wing center section, bays of the front and main aircraft supports, openings and hatches.

3.2.4 Nose part of fuselage

In the nose of the fuselage, a nose cone is installed with a radar station located in it, there is a cockpit canopy and a cockpit floor with reinforcements for the seats of the crew commander, assistant crew commander, inspector and technician for airborne equipment, as well as a bays in the front support of the aircraft, closed by flaps driven by landing gear struts, technical compartments and bulkhead with crew door.

The bay window has a welded steel frame, in which are fixed the electrically heated windshields made of a block of silicate glass, side windows in the form of vents and rear windows made of organic glass.

3.2.5 Middle part of fuselage

In the middle part of the fuselage there is a transport cabin floor 13.21 m long and 2.728 m wide. The cargo floor consists of a set of lower frames, longitudinal beams and rails, and anti-slip skin. There are 7 rows of socket on the floor for mooring nodes for securing cargo, 4 rails for installing sections of removable airborne transport equipment. The flooring has removable panels for access to the underfloor space.

The boards of the cargo compartment are equipped with aircraft systems and assemblies for the installation of cargo hoist and seats for paratroopers.

The central power compartment in the middle part of the fuselage is made of prefabricated riveted panels, power sidewalls and bottom frames, made of forgings and stampings, to which the wing center section spars and the aircraft main supports are attached.

3.2.6 Aft part of fuselage

In the tail section of the fuselage there is a cargo hatch, a compartment for attaching the tail assembly with the superstructure of the fuselage between frames 50-53. on which the keel (киль) is fixed, as well as the APU compartment and the fuselage tip. At the fuselage tip there is an APU compartment with input and output devices, doors and fire bulkheads. The opening of the cargo hatch, located at frames 36 and 57, is edged with side beams and enforced with reinforced frames and diaphragms. The cargo hatch has on the threshold of the cargo floor on frame 36 width 2,728 m.

3.2.7 Doors, hatches

The entrance door (with a built-in gangway and a hydraulic lift driver) is located in the front part of the cargo compartment on the left side in the area of frames 8-10, with sizes of way 860 * 1800 mm in the fuselage.

The forward emergency hatch is located on the right sideboard of the aircraft in the area of frame 8-10 with the sizes of way 610 * 1220 mm in the fuselage.

Side doors for airdrop operations with sizes 900x1900 mm are located on both sides of the aircraft to ensure the possibility of airdrop of paratroopers in 2 streams, as well as they serve as outlets when an emergency landing on earth and water occurs. All doors have the ability to open manually both from the inside and outside the aircraft.

The entrance door, forward emergency hatch, side airdrop doors are Type 1 emergency exits and are used for emergency escape of the aircraft to the ground and water surface when transporting people in the transport cabin.

Each emergency exit is accessible and located in the most efficient location in the event of an evacuation. Emergency exits for crew members are cockpit canopy vents on the left and right sides in the cockpit cabin.

The cargo hatch consists of a ramp with side locks, hung on the sill of the cargo floor, tilted outward of the aircraft, two ramps, manually attached on the ground to the rear end of the frame, flaps with side and top locks, hung on the fuselage tip and supported on the rear end of the ramp and side beams of the way, as well as a pressurized flap based on a power bulkhead 50 and leaf. The leaf and hermetic flap opens into the fuselage.

On the side beams of the opening of the cargo hatch is installed locks, power hydraulic drivers and crossbar of ramp, as well as locks and thrust-stopper of leaf.

The structure of the ramp, leaf and pressurized flap is made of transverse and longitudinal beams, hermetic covering and outer skin. The structure of the pressurized flap is made of longitudinal beams, pressurized covering and outer skin.

The ramp with an open cargo hatch provides on earth a movement on roller equipment of standard pallets and containers, airdrop in flight of cargo on the platform, and in the closed position the carriage on it of cargo weighing up to 2t.

For this, the ramp has sockets for mooring nodes and rails, similar to the structure of the cargo floor.

Control of the cargo hatch is provided from the hydraulic system 2 and the hydraulic network of the reserve aircraft with an electrical panel in the cargo compartment and controls in the cockpit, where there is an indication of the positions of the cargo hatch assemblies, doors and crew emergency exit.

3.2.8 Empennage

Empennage of the aircraft is single-finned, T-shaped, with a fixed stabilizer mounted on the fin. The tail consists of a vertical and horizontal tail, fairing and streamer.

The vertical tail consists of a fin, rudder and dorsal fin. The fin consists of a caisson, a nose and a tail parts. The fin with the fuselage has a split joint along the upper surface of the superstructure on the tail part of fuselage, a stabilizer is attached to the fin. The fin box is of metal construction (made of aluminum alloys), consists of front and rear spars, twelve ribs, right and left panels, reinforced with stringers. The nose part of the fin is metal (made of aluminum alloys), it consists of a removable toe, root, end and typical ribs, power beam and skin. The tail section of the fin is made of panels and diaphragms.

The tail fin panels are made of three-layer polymeric composite material. Part of the panels are made of aluminum alloys. On the rear spar there are rudder mounting brackets made of aluminum alloys.

The fin is joined to the fuselage along the frame 50 along the front spar, and along the frame 53 along the rear spar. The rudder is made mainly of composite materials and consists of a frame (skin, ribs and tips), a spar, a bow and has six brackets, three of which are connected to the steering drives. The brackets are made of aluminum alloys. The dorsal fin is attached to the fuselage, the fuselage spine fairing and the fin, and consists of a radio compartment made of a metal toe cap with diaphragms and side panels of a honeycomb structure made of polymeric composite material, a metal aviation power unit compartment with a hatch on the left and a diaphragm between it and the radio compartment, as well as a rib at the junction of the dorsal fin with the fuselage spine fairing.

The horizontal tail consists of a stabilizer and elevators separated by a fairing and a drain. The stabilizer is made of two consoles, each consisting of a caisson, nose and tail parts and tips. The caisson part of the metal structure (made of aluminum alloys) and consists of front and rear spars, top and bottom panels, reinforced with stringers and fifteen beam-type ribs. The nose section is attached to the front stabilizer member. The nose part is a removable toe cap and consists of a hermetic chamber shell, walls and diaphragms of manufactured and aluminum alloys.

The tail section of the stabilizer is attached to the rear spar, it is made of aluminum diaphragms and panels (made of three-layer PCM construction, part of the panels are made of aluminum alloys).

The tail section includes a booster compartment. The elevator mounting brackets are installed on the rear spar. The end of the stabilizer is of a metal structure (aluminum alloys) and consists of a toe, ribs, skin, diaphragms and brackets for attaching static electricity arresters.

An elevator is attached to each stabilizer console. The elevator is mainly of a composite structure, consists of a frame (skins with ribs and tips), a spar, a bow and brackets for its attachment points to the stabilizer, three of them are connected to control actuator. The hinge unit brackets are made of aluminum alloys. The fairing consists of an aluminum alloy frame, to which transparent fiberglass radio casings are attached. The end plate is installed in the area of the stabilizer and fin joint and consists of the front and tail parts. The front part is metal (aluminum alloys), it consists of a frame, panels with hatches, beams and caps.

The tail section consists of composite panels, aluminum frames, caps, metallization buss with static arresters and a tip with a tail light. For maintenance and inspection of the structure and systems, hinged and removable panels and hatches covered with bung are provided. The bottom surfaces of the stabilizer, elevator, root rib and rudder hinge brackets have drain holes for condensation drainage.

3.2.9 Landing gear

The landing gear of the aircraft provides operation with artificial surface runways and prepared unpaved runways. The aircraft is equipped with a tricycle landing gear consisting of a front support and main supports (two struts on each side).

On the sill frame of the fuselage, two height-adjustable cargo supports with a hydraulic drive are installed, which allows you to change the height of the sill depending on the height of the platform of the reloading device or truck. The main parts of the chassis are made of forgings, including large-sized, high-strength steel and titanium.

The front support consists of a semilevered type shock absorber with a built-in two-chamber shock absorber, two non-brake wheels, a steering mechanism, locks for extended and retracted positions and a hydraulic cylinder for landing and landing gear.

Each suspension strut of the main aircraft support is semilevered type with built-in shock absorber and one brake wheel. In the extended position, the rack is held by a folding brace. The struts are retracted by a hydraulic cylinder in the transverse direction to the aircraft axis into undercarriage bay under the fuselage floor and landing gear fairings. The undercarriage bay are closed with doors mechanically connected to the struts.

The system for adjusting the height of the cargo floor of the main supports of the aircraft provides a decrease in the height of the rear sill from the ground from 1430 mm (corresponds to the mass of an empty loaded aircraft) to 1042 mm and the ramp angle relative to the ground is 9.5 degrees, ladders 12 degrees.

The landing gear is retracted and extended by using a hydraulic system. In case of failure of the main and backup hydraulic landing gear systems, a backup mechanical landing gear release is provided.

During the landing gear retraction after the takeoff run, the braking system automatically brakes the wheels of the main supports. The struts of the main aircraft supports in the retracted position and the attachment points to the fuselage are placed in the landing gear fairing.

3.2.10 Crew cabin

There are four workplaces in the cockpit: the crew commander, the assistant crew commander, the inspector, and an additional workplace (accompanying or flight technician for aviation and airborne transport equipment). Workplaces are located in the direction of flight.

Pilots' workplaces are equipped with a sight for setting the seats in the working position. Pilots' seats are equipped with an adjustment for individual anthropometric data. All workplaces are equipped with the necessary emergency equipment. On the left side, in the rear of the cabin, behind the crew commander's workplace, there is a toilet room and a wardrobe for personal belongings of the crew members.

The cockpit floor level is located above the cargo compartment floor level: a step is installed to access the cockpit. For emergency escape of the crew on land or water, movable and removable lantern vents are used. Safety ropes are provided over the vents. Emergency radio beacons are provided in the cockpit. To meet the regulatory requirements for noise in the cockpit, the inner surface of the side is covered with a shock-absorbing coating and heat-sound insulation, the decorative edging serves as the second sound-insulating wall.

3.2.11 Cargo cabin

In the front part of the fuselage, between frames 8 and 10 on the left side of board, a ramp door is used to enter and exit the aircraft, the right front emergency hatch is used as an emergency exit.

To ensure a comfortable environment, the transport cabin is faced with interior panels. In addition to the decorative and ergonomic functions, the edging panels of the transport cabin protect the assemblies and equipment of aircraft systems from damage and outside interference. The edging panels also act as a second sound protective wall.

Edging panels provide for the installation of landing seats. As decorative and finishing materials for the interior panels of the cargo compartment, paint-and-lacquer coating is used.

For the convenience of servicing aircraft systems, the interior panels are hinged or easily removable. To meet the regulatory requirements for noise in the cargo compartment, the inner surface of the fuselage side is covered with heat and sound insulations. The design of the cargo compartment meets the requirements for class "E" cargo compartments.

3.3 Geometry calculations for the main parts of the aircraft

Layout of the aircraft consists from composing the relative disposition of its parts and constructions, and all types of the loads (passengers, luggage, cargo, fuel, and so on).

Calculations of the main parts of the aircraft are performed according to data given in appendix A. Choosing the scheme of the composition and aircraft parameters is directed by the best conformity to the operational requirements.

3.3.1 Wing geometry calculation

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

Full wing area with extensions is calculated according to formula:

$$S_{wfull} = \frac{m_{0*g}}{P_0} \tag{3.1}$$

$$S_{wfull} = \frac{54665 * 9{,}81}{2866} = 187{,}1\ (m^2)$$

$S_w = 187{,}1\ (m^2)$ this value is not suitable for my aircraft, so I accept the value of the prototype $S_w = 98{,}58\ (m^2)$

Wing span is calculated according to formula:

$$l = \sqrt{S_w * \lambda} \tag{3.2}$$

$$l = \sqrt{98{,}58 * 9{,}33} = 30{,}32\ (m)$$

Root chord is calculated according to formula :

$$b_0 = \frac{2S_w * \eta_w}{(1+\eta_w) * l_w} \tag{3.3}$$

$$b_0 = \frac{2 * 98,58 * 4,61}{(1 + 4,61) * 30,32} = 4,85\ (m)$$

Tip chord is calculated according to formula:

$$b_t = \frac{b_0}{\eta_w} \tag{3.4}$$

$$b_t = \frac{4,85}{4,61} = 1,3\ (m)$$

At a choice of power scheme of the wing we determine quantity of longerons and its position, and the places of wing portioning.

On the modern aircraft we use xenon double – or triple – longeron wing; longeron wing is common to the light sport, sanitary and personal aircrafts. Our aircraft has three longerons. I use the geometrical method of mean aerodynamic chord determination (figure 3.1).

Mean aerodynamic chord is equal:

$$b_{MAC} = 3,4165\ (m)$$

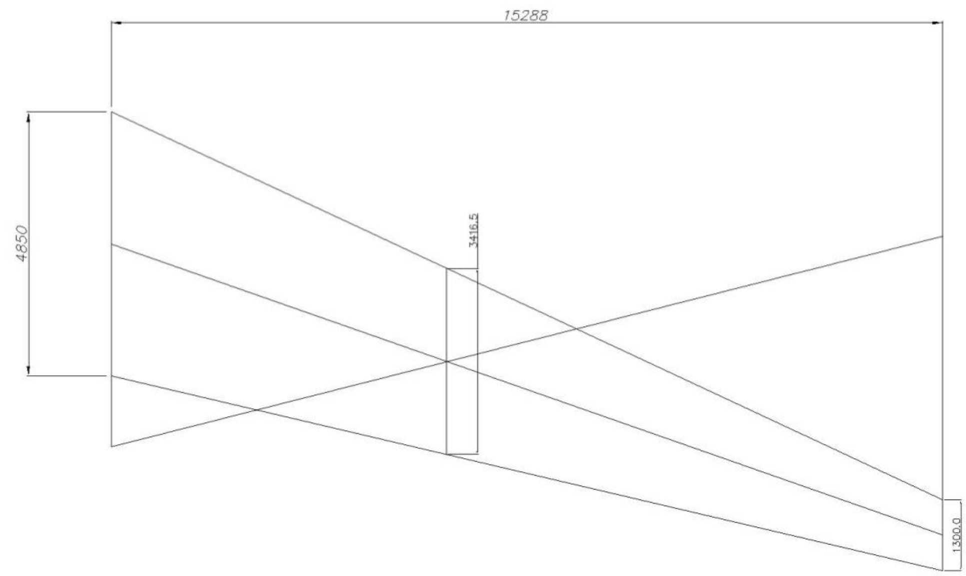

Figure 3.1 – Determination of mean aerodynamic chord

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 is calculated according to formula:

$$l_{ail} = (0,3 \dots 0,4)\frac{l_w}{2} \tag{3.5}$$

$$l_{ail} = 0,375 * \frac{30,32}{2} = 5,685\ (m)$$

Aileron area is calculated according to formula:

$$S_{ail} = (0,05 \dots 0,08)\frac{S_w}{2} \tag{3.6}$$

$$S_{ail} = 0,065 * \frac{98,58}{2} = 3,204\ (m^2)$$

Chord of aileron is calculated according to formula:

$$C_{ail} = (0.22 \dots 0.26) b_i \tag{3.7}$$

$$C_{ail} = 0,24 * 1,709 = 0,41\ (m)$$

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. So,l_{ail} = 0.122. 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 $S_{axinail} \leq (0.25 \dots 0.28)\ S_{ail} = 0.26 * 3.204 = 0.83\ (m^2)$

Inner axial compensation $S_{inaxinail}$ = (0.3..0.31) S_{ail};

Area of ailerons trim tab.

For two engine airplane:

$$S_{trtab} = (0{,}04 \ldots 0{,}06)S_{ail} \quad (3.8)$$

$$S_{trtab} = 0{,}05 * 3{,}204 = 0{,}16\ (m^2)$$

Range of aileron deflection

Upward $\delta'_{ail} \geq 25^\circ$;

Downward $\delta''_{ail} \geq 15^\circ$.

The aim of determination of wing high-lift devicesgeometrical parameters is the providing of take off 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 $C_{y\max bw}$ and determine necessary increase for this coefficient $C_{y\max}$ for the high-lift devices outlet by the formula: $\Delta C_{y\max} = (\frac{C_{y\max l}}{C_{y\max bw}})$.

Where $C_{y\max l}$ 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).

In the modern design the rate of the relative chords of wing high-lift devices is:

b_{sf} = 0.25..0.3 – for the split edge flaps;

b_f = 0.28..0.3 – one slotted and two slotted flaps;

b_f = 0.3..0.4 – for three slotted flaps and Faylers flaps;

b_s = 0.1..0.15 – slats.

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 longeron structurally-power schemes.

3.3.2 Fuselage layout

During the choice of the shape and the size of fuselage cross section we need to come from the aerodynamic demands (streamlining and cross section).

Applicable to the subsonic passenger and cargo aircrafts (V <800 km/h) wave resistance doesn’t affect it. So we need to choose from the conditions of the list values friction resistance C_{xf} and profile resistance C_{xp}.

During the transonic and subsonic flights, shape of fuselage nose part affects the value of wave resistance C_{xw}. Application of circular shape of fuselage nose part significantly diminishing its wave resistance.

For high subsonic airplanes fuselage nose part has to be:

$$l_{fnp} = (2 \dots 3)D_f \tag{3.9}$$

$$l_{fnp} = (2 \dots 3)D_f = 2 * 3{,}9 = 7{,}8\ (m)$$

Except aerodynamic requirements consideration during the choice of cross section shape, we need to consider the strength and layout requirements.

For ensuring of the minimal weight, the most convenient fuselage cross section shape is circular cross section. In this case we have the minimal fuselage skin width. As the partial case we may use the combination of two or more vertical or horizontal series of circles.

For cargo aircrafts the aerodynamics is not so important in the fuselage shape choice, and the cross section shape is may be close to rectangular one.

To geometrical parameters we concern: fuselage diameter D_f; fuselage length l_f; fuselage aspect ratio λ_f; fuselage nose part aspect ratio λ_{np}; tail unit aspect ratio λ_{TU}. Fuselage length is determined considering the aircraft scheme, layout and airplane center-of-gravity position peculiarities, and the conditions of landing angle of attack α_{land} ensuring.

Fuselage length is calculated according to formula:

$$l_f = \lambda_f * D_f \tag{3.10}$$

$$l_f = 7{,}68 * 3{,}9 = 29{,}95\ (m)$$

Fuselage nose part aspect ratio is calculated according to formula:

$$\lambda_{fnp} = \frac{l_{fnp}}{D_f} \tag{3.11}$$

$$\lambda_{fnp} = \frac{7{,}8}{3{,}9} = 2$$

Length of the fuselage rear part is calculated according to formula:

$$l_{frp} = \lambda_{frp} * D_f \tag{3.12}$$

$$l_{frp} = 2{,}2 * 3{,}9 = 8{,}58\ (m)$$

During the determination of fuselage length we seek for approaching minimum mid-section S_{ms} from one side and layout demands from the other.

For passenger and cargo airplanes fuselage mid-section first of all comes from the size of passenger saloon or cargo cabin.

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.

Step of normal bulkhead in the fuselage construction is in the range of 350...550mm, depends on the fuselage type and class of passenger saloon.

Form the design consideration with the diameter less than 2800mm we don't use such shape and we follow to the intersecting circles cross section. In this case the flour of the passenger saloon is done in the plane of are closing.

3.3.3 Lavatories

The number of lavatories I choose according to the original airplane and it is equal:

$$n_{lav} = 1$$

Area of lavatoryis:

$$S_{lav} = 1.5m^2$$

Width of lavatory:1m. Toilets design similar to the prototype.

3.3.4 Layout and calculation of basic parameters of tail unit

One of the most important tasks of the aerodynamic layout is the choice of tail unit placing. For ensuring longitudinal stability during overloading its center of gravity should be placed in front of the aircraft focus and the distance between these points, related to the mean value of wing aerodynamic chord, determines the rate of longitudinal stability.

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

Where m^{Cy}_x –is the moment coefficient;x_T.x_F- center of gravity and focus coordinates.Ifm^{Cy}_x=0, than the plane has the neutral longitudinal static stability, if m^{Cy}_x>0, than the plane is statically instable. In the normal aircraft scheme (tail unit is behind the wing), focus of the combination wing – fuselage during the install of the tail unit of moved back.

Static range of static moment coefficient: horizontal A_{htu}, vertical A_{vtu} given in the table with typical arm Htu and Vtu correlations.

Using table we may find the first approach of geometrical parameters determination.

$A_{VTU} = (0.05 \dots 0.08) \rightarrow A_{VTU} = 0{,}06$

$A_{HTU} = (0.8 \dots 1.1) \rightarrow \; A_{HTU} = 0{,}9$

Determination of the tail unit geometrical parameters.

Area of vertical tail unit is calculated according to formula:

$$S_{VTU} = (0.18 \dots 0.25)S_w \tag{3.13}$$

$$S_{VTU} = 0{,}21 * 98{,}58 = 21{,}054 \; (m^2)$$

or

$$\mathrm{S_{VTU}} = \frac{\mathrm{A_{VTU} * S_w * l_w}}{\mathrm{L_{VTU}}} \tag{3.14}$$

$$S_{VTU} = \frac{0{,}06 * 98{,}58 * 30{,}32}{7{,}5} = 23{,}9 \; (m^2)$$

Area o horizontal tail unit is calculated according to formula:

$$S_{HTU} = (0.12 \dots 0.2)S_w \tag{3.15}$$

$$S_{HTU} = 0{,}19 * 98{,}58 = 18{,}87 \; (m^2)$$

or

$$\mathrm{S_{HTU}} = \frac{\mathrm{A_{HTU} * S_w * b_{MAC}}}{\mathrm{L_{HTU}}} \tag{3.16}$$

$$S_{HTU} = \frac{0{,}9 * 98{,}58 * 3{,}4165}{16{,}2} = 20{,}27 \; (m^2)$$

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

Determination of the elevator area and direction:

Altitude elevator area is calculated according to formula:

$$S_{el} = 0{,}27 * S_{HTU} \tag{3.17}$$

$$S_{el} = 5{,}22 \; (m^2)$$

Rudder area is calculated according to formula:

$$S_{rud} = 0{,}24 * S_{vtu} \qquad (3.18)$$

$$S_{rud} = 5{,}05\ (m^2)$$

Choose the area of aerodynamic balance.

0.3≤M≤0.6

S_{eb}=(0.22..0.25)S_{ea}

S_{rb}=(0.2..0.22)S_{rd}

Elevator balance area is:

$$S_{eb} = 0{,}27 * S_{HTU} \qquad (3.19)$$

$$S_{eb} = 5{,}09\ (m^2)$$

Rudder balance area is calculated according to formula:

$$S_{rud} = 0{,}24 * S_{vtu} \qquad (3.20)$$

$$S_{rud} = 5{,}05\ (m^2)$$

The area of altitude elevator trim tab is calculated according to formula:

$$S_{te} = 0{,}08 * S_{el} \qquad (3.21)$$

$$S_{te} = 0{,}42\ (m^2)$$

Area of rudder trim tab is equal:

$$S_{tr} = 0{,}06 * S_{rud} \qquad (3.22)$$

$$S_{tr} = 0{,}303\ (m^2)$$

Tip chord of horizontal stabilizer is calculated according to formula:

$$b_{tip}^{HTU} = \frac{2 * S_{HTU}}{(\eta_{HTU} + 1) * l_{HTU}} \qquad (3.23)$$

$$b_{tip}^{HTU} = \frac{2 * 18{,}87}{(2{,}1 + 1) * 9{,}4} = 1{,}29(m)$$

Root chord of horizontal stabilizer is calculated according to formula:

$$\mathrm{b}_{\mathrm{root}}^{\mathrm{HTU}} = \eta_{\mathrm{HTU}} * \mathrm{b}_{\mathrm{tip}}^{\mathrm{HTU}} \quad (3.24)$$

$$b_{root}^{HTU} = 2{,}1 * 1{,}29 = 2{,}709\ (m)$$

Tip chord of vertical stabilizer is calculated according to formula:

$$\mathrm{b}_{\mathrm{tip}}^{\mathrm{VTU}} = \frac{2 * \mathrm{S}_{\mathrm{VTU}}}{(\eta_{\mathrm{VTU}} + 1) * \mathrm{l}_{\mathrm{VTU}}} \quad (3.25)$$

$$b_{tip}^{VTU} = \frac{2 * 21{,}054}{(0{,}99 + 1) * 4{,}76} = 4{,}44\ (m)$$

Root chord of vertical stabilizer is calculated according to formula:

$$b_{root}^{VTU} = \eta_{VTU} * b_{tip}^{VTU} \quad (3.26)$$

$$b_{root}^{VTU} = 0{,}99 * 4{,}44 = 4{,}39\ (m)$$

3.3.5 Landing gear design

In the primary stage of design, when the airplane center-of-gravity position is defined and there is no drawing of airplane general view, only the part of landing gear parameters may be determined.

Main wheel axel offset is calculated according to formula:

$$B_m = (0.15 \ldots 0.2) b_{MAC} \quad (3.27)$$

$$B_m = 0{,}17 * 3{,}4165 = 0{,}581\ (m)$$

With the large wheel axial offset the lift-of of the front gear during take of is complicated, and with small, the drop of the airplane on the tail is possible, when the loading of the back of the airplane comes first. Landing gear wheel base comes from the expression:

$$B = (0.3 \ldots 0.45)L_f \tag{3.28}$$

$$B = 0,38 * 29,95 = 11,37\ (m)$$

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

Front wheel axial offset will be calculated according to formula:

$$B_n = B - B_m \tag{3.29}$$

$$B_n = 11,37 - 0,581 = 10,789\ (m)$$

Wheel track is calculated according to formula:

$$T = (0.3 \ldots 1.4)B \tag{3.30}$$

$$T = 0,37 * 11,37 = 4,37\ (m)$$

On a condition of the prevention of the side nose-over the value K should be > 2H, where H – is the distance from runway to the center of gravity.

$$H_{cg} = (0.08 \ldots 0.1)D_f = 0,09 * 3,9 = 0,351\ (m) \tag{3.31}$$

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

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

The load on the wheel is determined:

K_g = 1.5...2.0 – dynamics coefficient.

Nose wheel load is calculated according to formula:

$$P_n = \frac{B_m * M_0 * 9.81 * K_g}{B * z} \tag{3.32}$$

$$P_n = \frac{0,581 * 54665 * 9,81 * 1,7}{11,37 * 2} = 23292,3\ (N)$$

Main wheel load is calculated according to formula:

$$P_m = \frac{(B - B_m) * M_0 * 9.81}{B * n * z} \tag{3.33}$$

$$P_m = \frac{(11,37 - 0,581) * 54665 * 9,81}{11,37 * 4 * 2} = 63607,6\ (N)$$

It was chosen aviation tires for designing aircraft for main and nose landing gear. Size parameters is performed in table 3.2.

Table 3.2 - Aviation tires for designing aircraft

Main gear		Nose gear	
Tire size	Ply rating	Tire size	Ply rating
1140*458 mm	16	700*270 mm	8

3.3.6 Choice and description of power plant

TA18-100 is an aviation auxiliary gas turbine engine developed in 2000 at PJSC NPP Aerosila. Designed for use on airplanes and helicopters.

AGTE TA18-100 meets the requirements for use on narrow-body aircraft with a capacity of up to 100 seats and heavy helicopters. The engine provides an air start of sustainer engines of aircraft. It also provides 115/200 volt AC power and serves to supply air to the air conditioning system.

Characteristics of AGTE TA18-100:

- Equivalent air power - 256 kW.
- Selectable AC power - 60 kVA.
- Bleed air consumption - 1.27 kg / s.
- Bleed air pressure - 4.52 kgf / cm².

- Bleed air temperature - 210 ° C.
- Fuel consumption - 132 kg / h
- Altitude of launch and operating mode - 9000 m.
- Working temperature range - ± 60 ° C.
- Initial assigned resource - 2000/4000 hours / starts.
- Assigned resource - 12000/15000 hours / starts.
- Weight (without generator) - 150 kg.
- Overall dimensions - 1076 × 684 × 675 mm.

3.4 Determination of the aircraft center of gravity position

3.4.1 Determination of centering of the equipped wing

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

The example list of the mass objects for the aircraft, where the engines are located under the wing, included the names given in the table 3.3.

The example list of the mass objects for the aircraft, where the engines are located in the wing, included the names given in the table 3.3. The mass of AC is 54665 kg.

Coordinates of the center of power for the equipped wing are defined by the formulas:

$$X_w^` = \frac{\sum m_i^` * x_i^`}{\sum m_i^`} \tag{3.34}$$

Table 3.3 - Trim sheet of equipped wing masses

№	Name	Mass		C.G. coordinates	Moment (kgm)
		Units	total (kg)		
1	2	3	4	5	6
1	Wing (structure)	0,14604	7983,28	1,47	11728,19
2	Fuel system, 40%	0,00144	78,72	1,50	118,33
3	Control system, 30%	0,00213	116,44	2,05	238,68
4	Electrical equip. 30%	0,00621	339,47	0,34	115,98
5	Anti-icing system 50%	0,0083	453,72	0,34	155,01
6	Hydraulic system, 70%	0,01323	723,22	2,05	1482,52
7	Engine	0,08047	4398,89	-2,1	-9237,67
8	Equiped wing	0,17735	14093,73	0,33	4601,05
9	Nose landing gear	0,004944	270,26	-10,26	-2771,83
10	Main landing gear	0,044838	2451,07	1,11	2713,33
11	Fuel	0,12604	6889,98	1,47	10122,03
	Equiped wing	0,433642	23705,04	0,62	14664,59

3.4.2 Determination of the centering of the equipped fuselage

Origin of the coordinates is chosen in the projection of the nose of the fuselage on the horizontal axis. For the axis X the construction part of the fuselage is given. The example list of the objects for the AC, which engines are mounted under the wing, is given in table 3.4.

The CG coordinates of the FEF are determined by formulas:

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

We can find fuselage center of gravity coordinate X_f by divided sum of mass moment of the fuselage ($m_i^{'}$, X_i) on sum of total mass of fuselage ($m_i^{'}$):

$$X_f = \sum m_i \bullet X_i / \sum m_i = 16.22\ (m)$$

After we determined the center of gravity (CG of FEW) and fuselage, we construct the moment equilibrium equation relatively fuselage nose:

$m_f \bullet x_f + m_w \bullet (x_{MAC} + x'_w) = m_0 \bullet (x_{MAC} + C)$

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

$$X_{MAC} = \frac{m_f * x_f + m_w * x_w - m_0 * c_n}{m_0 - m_w} \quad (3.35)$$

$$X_{MAC} = 12{,}061 \text{ (m)}$$

where, m_0 – AC takeoff mass, kg; m_f – mass of FEF, kg; m_w – mass of FEW, kg; C – distance from MAC leading edge to the CG point, determined by the designer.

Table 3.4 - Trim sheet of equipped fuselage masses

№	Objects	Mass		Coordinates of C.G.	Moment (kgm)
		Units	Total (kg)		
1	2	3	4	5	6
1	Fuselage	0,13782	7533,93	14,975	112820,61
2	Horizontal tail unit	0,01865	1019,50	0,8512	867,80
3	Vertical tail unit	0,02186	1194,97	1,8632	2226,48
4	Radar equipment	0,0059	322,52	1,08	348,33
5	Instrument panel	0,0103	563,05	1,93	1086,69
6	Air-navigation system	0,0088	481,05	2,216	1066,01
7	Radio equipment	0,0044	240,53	2,16	519,54
8	Toilet 1	0,0002	10,93	3,7	40,45
9	Cargo compartment equipment	0,0002	10,93	11,45	125,18
10	Control system, 70%	0,00497	271,69	13,975	3796,79
11	Electrical equipment, 70%	0,01449	792,09	14,975	11861,64
12	Hydraulic system, 30%	0,00567	309,95	17,97	5569,81
13	Air conditioning system equipment	0,00332	181,49	14,975	2717,78
14	Decorative paneling	0,0208	1137,03	14,975	17027,05
15	Heat and sound isolation	0,0078	426,39	14,975	6385,15

Ending of table 3.4.

1	2	3	4	5	6
16	Anti-icing system, 30%	0,00498	272,23	8,985	2446,01
17	Additional equipment	0,0082	448,25	13,975	6264,34
18	Fuel system, 60%	0,00216	118,08	13,975	1650,12
19	Auxiliary power unit	0,00821	448,79	15,5	6956,39
20	Equiped fuselage without comercial loads	0,28873	15783,43	16,22	183776,16
21	Cargo	0,2444	13360,13	14,975	200067,89
22	Non-typical equipment	0,033228	1816,41	14,975	27200,72
	Total	0,566358	30959,97	13,28	411044,76

3.4.3 Calculation of center of gravity positioning variants

The list of mass objects for centre of gravity variant calculation given in Table 3.5 and Center of gravity calculation options given in table 3.6, completes on the base of both previous tables.

Table 3.5 - Calculation of C.G. positioning variants

Name	Mass, kg	Coordinates	Moment
Object	m_i	C.G., m	Kgm
Equiped wing without fuel and L.G.	14093,73	8,995	126815,38
Nose landing gear (retracted)	270,26	1,9	513,51
Main landing gear (retracted)	2451,07	13,3	32599,22
Fuel	7008,05	11,5	80592,61
Equiped fuselage	15783,43	16,22	256007,16
Cargo	13360,17	14,975	200067,89
Nose landing gear (opened)	270,26	2,9	783,76
Main landing gear (opened)	2451,07	14,3	35050,29

Table 3.6 - Airplanes C.G. position variants

№	Name of objects	Mass, kg	Momen, kgm	C.G., m	Centering
1	Take-off mass (L.G. extended)	54665	696595,76	12,72	19,15
2	Take-off mass (L.G. retracted)	54665	699317,09	12,76	20,61
3	Landing variant (L.G. extended)	51182,91	655193,81	12,80	21,65
4	Transportation variant (without payload)	39606,54	499249,21	12,61	15,92
5	Parking variant (without fuel and payload)	32598,49	415935,27	12,76	20,43

Conclusion to the part 3

In this part it was carried out the analysis of aircraft prototypes, made a choice of the main characteristics of the designing aircraft, a brief description of all parts of the aircraft, determined structural parameters of the fuselage layout.

After analyzes the data of the prototypes, it was chosen the optimal parameters for designing aircraft: high - wing configuration monoplane with freely carrying tail unit. High-wing aircraft has a lot of advantages, such as: facilities installation on the wing, since engine and propeller clearance is higher and safer compare with low wing configuration; increases dihedral effect; wing will produce more lift compare with mid-, low-wing. Freely carrying tail unit have axial aerodynamic compensation and 100% equilibrium.

Also it was choose tricycle landing gear, which have the next advantages: ease of maneuvering when using the system of rotation of the front wheels, more intense braking on the run and the possibility of high-speed landing, improved cab view when driving on the ground.

Also in this part it was carried out determination of the center mass position characteristics. Airplane center of gravity position variants are equal from 12,61 m to 12,80 m these values correspond to desire for that type of aircraft. It was carried out calculations of the main parts of an aircraft, such as span of the wing – 30.32 m, area of the wing – 98,58 m, length of the fuselage is 29,95 m, base of landing gear is 11,37 m and track is 4,37 m. We have also checked the mass position of the main parts of the aircraft and main equipment and furnishing by its distance from the main aerodynamic chord. The wing MAC leading edge position relative to fuselage is equal to 12,061 m, which corresponds to desired values of the designing aircraft. After designing of the wing and the fuselage we have made the calculations of the center of gravity determination of the equipped aircraft. Also it was carried out selection of engines which meet the requirements for the designed aircraft, determined the geometrical parameters of the fuselage layout.

4 DEVELOPMENT OF ELEMENTS OF CONTEINER DELIVERY SYSTEM

In this chapter of the diploma work will be developed element of a system for aerial cargo delivery by the gravity method, which is named as buffer stop, for middle range aircraft. Buffer stop is one the most significant element of container delivery system, which is used to hold the cargo in containers in the X-axis forward during transportation and airdropping flights, prevent abnormal emergencies during the flight and at the process of dropping cargo from the aircraft.

For the development of new buffer stop it is necessary to obtain input data about aircraft performances and roller equipment for following development of installation, chose container type suitable for container delivery system, determine centers of gravity of chosen containers for correct layout it on aircraft. Also it is necessary to define main requirements to buffer stop, chose structural elements of it and develop it by creation 3D models. After obtained designed installation it is important to calculate stress-strain state of it for confirmation of structural strength.

4.1 Input data to start development according to preliminary aircraft design

Aircraft performance characteristics:

- Length - 32.2 m
- Length of a cargo compartment with a ramp - 16,65 m
- Height of a cargo compartment - 2730 mm
- Width of a cargo compartment - 2728 mm
- Payload weight - 15-18 tons

Roller equipment characteristics and sizes are given according to the characteristics of aircraft prototypes:

- Height above the floor -55 mm
- Number of rollers in one section-8 pcs
- Length of one section - 1725 mm
- Distance between sections-514 mm
- Distance between lock beams - 1226 mm
- Number of sections in the cargo compartment - 14 pcs

- Height of lock beams - 132 mm

4.2 Parachute platform

Parachute platform is an integral part of platform`s paradrop equipment designed to accommodate the airdrop cargo and provides ground transportation, installation on the airdrop delivery equipment of the aircraft, drop and landing of these cargoes.

Therefore, it is necessary to have devices that would ensure the braking path of the load upon landing within the limits of permissible overloads, even with the maximum mass for a given parachute system. This function is performed by paradrop equipment, which provides paradrop of cargo and includes a platform.

A parachute platform is a device that is a power element for connecting a parachute system and securing cargo;

- power element that absorbs part of the kinetic energy when the landed object hits the ground;
- a platform for placement of various small-sized freights having at rather small own weight a strong design providing repeated application.

Upon entry into operation of the parachute system, the dynamic load Q, in the system cargo - parachute increases:

$$Q = G + \frac{m(V_0 - V_{ch})}{t_H} \quad (4.1)$$

where, G – weight of cargo, kgf; m - mass of cargo, kg; V_o – velocity before the parachute system starts working, km/h; V_{ch}- velocity of descent on the main parachutes, km/h; t - time of filling of a canopy (canopies), hour.

So, at weight of the airdrop cargo of 7000 kg loading at the moment of filling of parachute system will make about 12000 kg. Based on this, the platform is installed means of mooring the airdrop cargo, the mounting units of the parachute system of appropriate strength and placed energy-intensive shock absorbers, which can be placed both between the cargo and the platform and under the platform. In some cases, when it is necessary to significantly reduce the overload during landing, use a combined arrangement of shock absorbers. The use of energy-intensive shock absorbers, shock absorbers, which at the time of landing are able to absorb most of the kinetic energy of the cargo descending by parachute, is one of the main ways to slow down the load during landing.

As a shock-absorbing material, polyfoam, corrugated paper or aluminum foil glued in the form of removable honeycombs are used. The corrugated paper air self-filling shock absorbers are the most common used in our country.

Rigid foam shock absorbers are usually used when drop hull armored vehicles. Air shock absorbers are cloth bags with valves of constant cross-section or calibrated to a certain pressure. They have a high height and, therefore, a large braking distance and provide less load.

The vast majority of types of airdrop equipment are serial - general purpose, so there are no special mounting units for the parachute system. At different stages of development of paradrop methods for attaching the parachute system to the cargo, special suspension systems were made for each type of cargo (military equipment located in closed cabins or in large bags to which the parachute system was attached). The most successful was the placement of cargo on a flat rectangular pallet, called the parachute platform.

Military transport aircraft have several platforms with cargo prepared for parachute drop. They are equipped with special airdrop equipment, which provides:

- loading and placing cargo on parachute platforms with other airdrop equipment;
- fastening of cargo in the plane to the moment of drop;
- airdrop of cargo.

There are winches in the complete set of aircraft equipment for loading cargo. Some types of aircraft in addition to winches are equipped with electric hoists.

Depending on the weight of the load, overall dimensions and features of the device, the load can be carried out only by winches, only by hoists or by winches and hoists together.

In an airplane, parachute platforms are usually placed on roller tracks. They provide free movement of the platform on the cargo cabin along the longitudinal axis of the aircraft. Fastening of a platform in the aircraft to elements of the airdrop equipment is carried out by the special devices available on it. In airplanes equipped with roller equipment, such an element is a monorail, which provides directional movement of the platform, in airplanes with conveyors - conveyor chains.

4.3 Container type A-22

Container Delivery system method of airdrop uses A-22 containers to deliver miscellaneous items of supplies and equipment by means of cargo airdrop. The items are delivered by either high-velocity or low-velocity parachutes [16].

Up to 40 containers with up to 2200 pounds each can be delivered by this method, and it has proven itself to be an effective way to deliver supplies measuring no more than 4 ft × 4 ft × 4 ft and weighing between 501 lbs and 2200 lbs [16].

The A-22 container is placed on a plywood skid-board and several layers of energy-dissipating honeycomb are used under the A-22 to attenuate the ground impact shock and protect the supplies [16].

The A-22 cargo bag assembly is the most used assembly for aerial delivery loads such as food, medicines, ammunition, both military and human aid operations. The A-22 cargo bag assembly is an adjustable cotton duck cloth/nylon and nylon webbing container. It consists of a sling assembly, a cover and four suspension webs. The load may be rigged with or without the cover. The A-22 loads can be rigged for low-velocity drops with one G-12E as primary parachute for 501 to 2,200 pounds suspension weight. As alternate parachute can be used a G-14 in two cluster for 501 to 1,000 pounds and three cluster for 1,001 to 1,500 pounds. The A-22 also can be rigged for high-velocity drops with a 26-foot high velocity parachute for 501 to 2,200 pounds suspension weight, and 22-foot cargo extraction parachute as alternate parachute [15].

Characteristics of the A-22 container (for 10 loads):

- Width – 1219,2 mm;
- Length –1219,2 mm;
- Height – 25,4 mm;
- Material – wood;
- Rigged height – 1574 mm;
- Load weights – 501 to 2200 lbs (143 to 627 kg).

Maximum allowable displacement of the center of gravity of the cargo:

- longitudinal - 10%;
- transverse - 10%.

Weight of equipment used for airdrop:

$G_{max} = 1088\ kgf$;

$G_{min} = 256\ kgf$.

Download scheme:

- single-row: 10 platforms are placed in the center of the cargo compartment, on two tracks of roller equipment

In order to start work on a buffer stop installation, you need to calculate the center of gravity of one load. In all applications, the center of gravity is represented geometric, which in turn is not true. After all, for its calculation, the parameters whose force acts on the load from the outside are not accepted.

4.4 Calculation of the center of gravity for airdropped cargo in A-22 containers

The calculation of the equipment is made for the maximum weight of cargo for each place of installation of pallets.

In the event of an emergency landing, the device for airdrop is displaced by the barrier net, in other calculated cases they are held by the airdrop equipment. Devices for airdrop are kept from shifting forward by a buffer stop. Devices for airdrop are restrained from shifting back by special mooring belts. From displacement upwards or towards devices for airdrop are kept by lock beams. Installation on equipment and airdrop is carried out in groups of 2, 3, or 4 pallets of devices for airdrop.

In calculating the density of the cargo was taken the initial data from the instructions for packing, installation and operation of parachute cargo systems PCS-500.

To calculate the center of gravity, it is necessary to determine the height of the load and all elements of the device for airdrop. The height of the device for airdrop consists of the height of:

- pallet;
- amortization;
- cargo in the A-22 container;
- cargo parachute system (PS).

1. The height of the plywood pallet is - 25.4 mm (1 inch). Weight - 25 kg. Width and length - 1219.2 mm (LCLA 5F00 Interim 5F00 Rigging 5F00 Procedures).

2. Amortization consists of rows of paper honeycombs. The maximum number of paper honeycombs is 5 rows. The minimum number of paper honeycombs is 1 row. The thickness of one layer of honeycombs is 76.2 mm (3 inches). The weight of one layer of honeycombs is 2.27 kg (FM 4-20-152; LCLA 5F00 Interim; FM4-20-142).

The height of the load is determined relative to the maximum weight of 1000 kg at a given load density.

Density of cargo from six army shells:

- cargo weight 504 kg (without parachute system, platforms and amortization);
- height of packing of device for airdrop is 420 mm;
- width of packing of device for airdrop is 1176 mm;
- length of packing of device for airdrop is 1440 mm.

Determination of volume according to sizes of cargo:

$$V=a \cdot b \cdot c = 0{,}42 \cdot 1{,}176 \cdot 1{,}44=0{,}69\ (m^3) \tag{4.2}$$

Calculate density of cargo:

$$\rho = \frac{m}{V} = \frac{504}{0{,}69} = 728\ (\frac{kg}{m^3}) \tag{4.3}$$

At a given density and provided that the base of the cargo has dimensions of 1219.2x1219.2 mm, the height of the cargo is 466 mm.

Density of cargo with provisions:

- cargo weight 504 kg (without parachute system, platforms and amortization);
- height of packing of device for airdrop is 510 mm;
- width of packing of device for airdrop is of 1176 mm;
- length of packing of device for airdrop is 1400 mm.

Determination of volume:

$$V=a \cdot b \cdot c = 0{,}51 \cdot 1{,}176 \cdot 1{,}4=0{,}83\ (m^3) \tag{4.4}$$

Calculate density of cargo:

$$\rho = \frac{m}{V} = \frac{504}{0{,}83} = 600\ (\frac{kg}{m^3}) \tag{4.5}$$

At a given density and provided that the base of the cargo has dimensions of 1219,2x1219,2 mm, the height of the cargo is 565 mm.

For airdrop A-22 containers weighing up to 1000 kg, parachute system G-12 is used according to information of Capewell company [17].

Parachute system G-12 in the folded state:

- height 195 mm;
- length 890 mm;
- width 610 mm;
- weight 58 kg.

Thus, we have two calculation variants for each of the airdrop equipment as airdrop of army shells and airdrop of devices with provisions.

1. Airdrop of army shells.

The total height of the airdrop device is from 1228,6 mm to 1533,4 mm, m = 1093,27 kg and m=1102,39 kg.

Calculate center of gravity according to formula:

$$y_{cg} = \frac{y_1 * m_1 + y_2 * m_2}{m_1 + m_2} \tag{4.6}$$

where, y_1, y_2 – centers of each component; m_1 , m_2 – mass of each component.

Calculate center of gravity of cargo with 5 layers of honeycombs:

$$y_{cg} = \frac{12{,}7 * 25000 + 190{,}5 * 11350 + 766{,}7 * 1008000 + 97{,}5 * 58000}{25000 + 11350 + 1008000 + 58000} = 877\ (mm)$$

Calculate center of gravity of cargo with 1 layer of honeycomb:

$$y_{cg} = \frac{12{,}7 * 25000 + 38{,}1 * 2270 + 614{,}3 * 1008000 + 97{,}5 * 58000}{25000 + 2270 + 1008000 + 58000} = 583{,}7\ (mm)$$

The center of gravity is in the range from 583,7 mm to 877 mm, respectively. See figure 4.1.

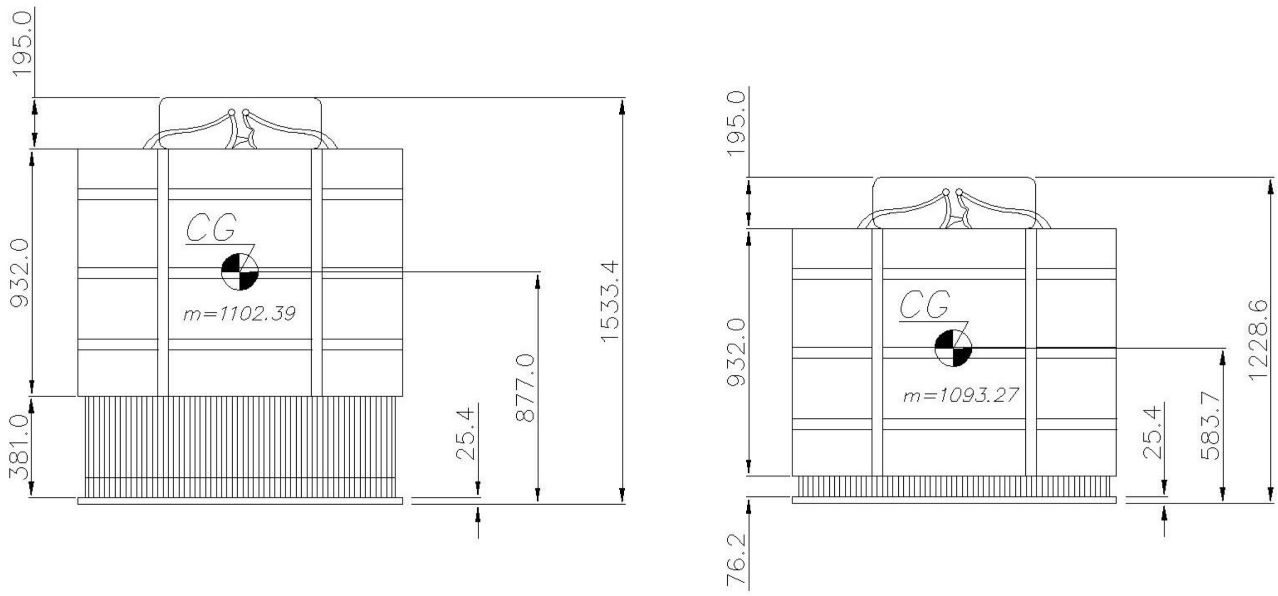

Figure 4.1 - Center of gravity of airdrop devices with army shells

2. Airdrop of devices with provisions

The total height of the airdrop device is from 1426,6 mm to 1731,4 mm, m = 1102,39 kg

Calculate center of gravity of cargo with 5 layers of honeycombs:

$$y_{cg} = \frac{12{,}7 * 25000 + 190{,}5 * 11350 + 856{,}7 * 1008000 + 97{,}5 * 58000}{25000 + 11350 + 1008000 + 58000} = 976{,}7 \text{ (mm)}$$

Calculate center of gravity of cargo with 1 layer of honeycomb:

$$y_{cg} = \frac{12{,}7 * 25000 + 38{,}1 * 2270 + 713{,}3 * 1008000 + 97{,}5 * 58000}{25000 + 2270 + 1008000 + 58000} = 685{,}5\ (mm)$$

The center of gravity is in the range from 685,5 mm to 976,7 mm, respectively. See figure 4.2.

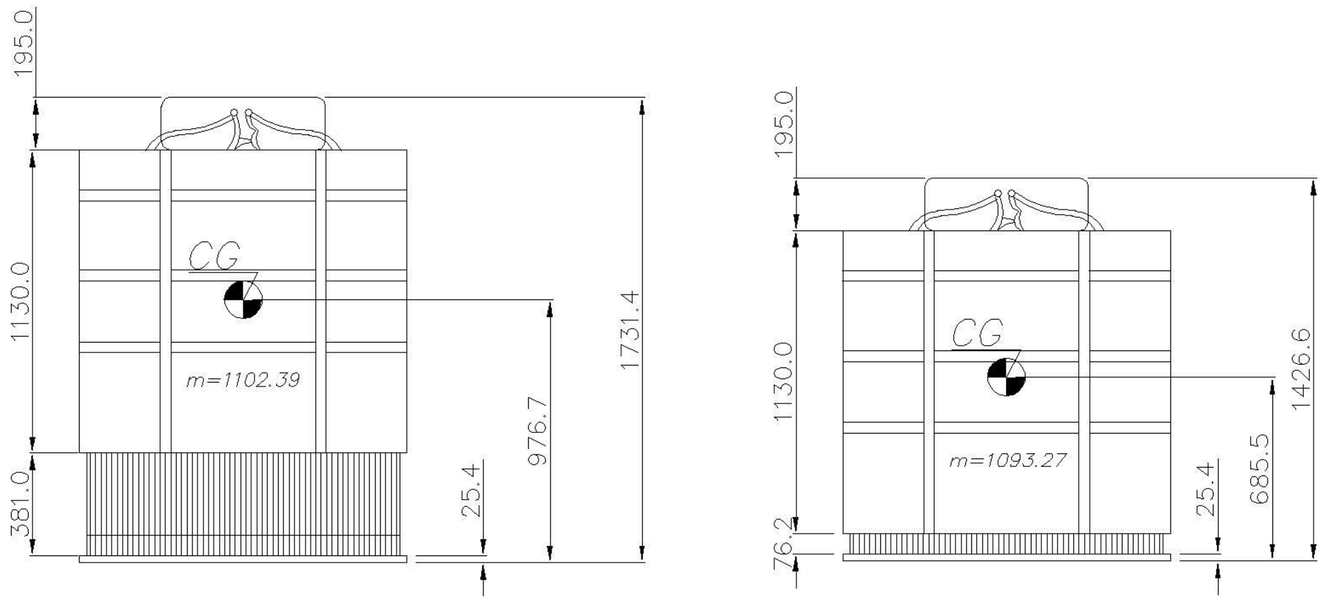

Figure 4.2 - Center of gravity of airdrop devices with provisions

4.5 Buffer stop development

Basic requirements for buffer stop installation:

- must be mobile;
- be compact;
- have a light construction;
- should have been easy to operate;
- withstand loads up to 12 tons;
- have a large area of contact with the load;
- cheap in manufacturing;
- could be fixed in any position on roller equipment.

The list of nuances that arose during the work on the installation:

- the length of the lower platform cannot exceed 800 mm. This is due to the fact that during the full loading of the cargo compartment (10 platforms), there is only space left with a length of 800 mm.
- the main load will be held by mooring belts, which are located opposite the center of gravity, because the struts can not physically withstand the load.
- also, it was decided to make the parts of the most persistent part the same and interchangeable, so that the part is cheap and easy to manufacture, and its components can

be easily found. Therefore, it was decided to take all the profiles from the range, and the operation of 'milling' to minimize the required minimum.

- mooring belts will be attached to the existing mooring ring, which has the ability to move on a spherical neck. This is due to the fact that the hooks that are attached to the ring will not go parallel to the load, but at an angle. Thus, they will not touch the load and the load will not be scrapped, but pulled.
- frame of a persistent surface, has to cover a front sheet of metal that the cargo did not fall through it.
- the lower platform will hold only two locks, as it is not possible to install four locks. The calculation of the bolts of the locks and the leash of the lock is given below.

4.5.1 Description of the design of the buffer stop

According to the results of the analysis of installations on military transport aircraft as the main constructive decision it was accepted that in principle the buffer stop will consist of:

- the basis which will be executed on the principle of the military pallet 88x108 MIL-P-27443E (USAF);
- a persistent wall which will accept loading from A-22 containers;
- struts between the abutment wall and the base;
- mooring straps (from the set of mooring equipment) between the abutment wall and mooring sockets on the floor of the aircraft.

The functional purpose of the buffer stop is to hold the cargo in containers A-22 in the X-axis forward during transportation and airdropping flights.

4.5.2 Development of a basis of buffer stop

According to the results of the development of the scheme of loading the aircraft with containers of type A-22, it was determined that the maximum length of the base can be 800 mm.

The base must be mounted on roller equipment and fixed on the X axis with a special bolt located in the lock beam, and on the Y and Z axes by the construction of the lock beam.

Structurally, the base is a set of transverse and longitudinal force elements connected to each other and the upper and lower skin on these force elements.

The first stage of development was the design of the main elements, locking rails, the configuration of which is made in accordance with the international standard MIL-P-27443E (USAF). This configuration allows you to fix the abutment with side beam (ригель). This mounting method is borrowed from the 463L logistics system and is used in NATO countries, it is universal, reliable and simple, and it is also used for fixing airdropping and cargo platforms. The sizes of lock rails correspond to figure 4.3and 4.4.

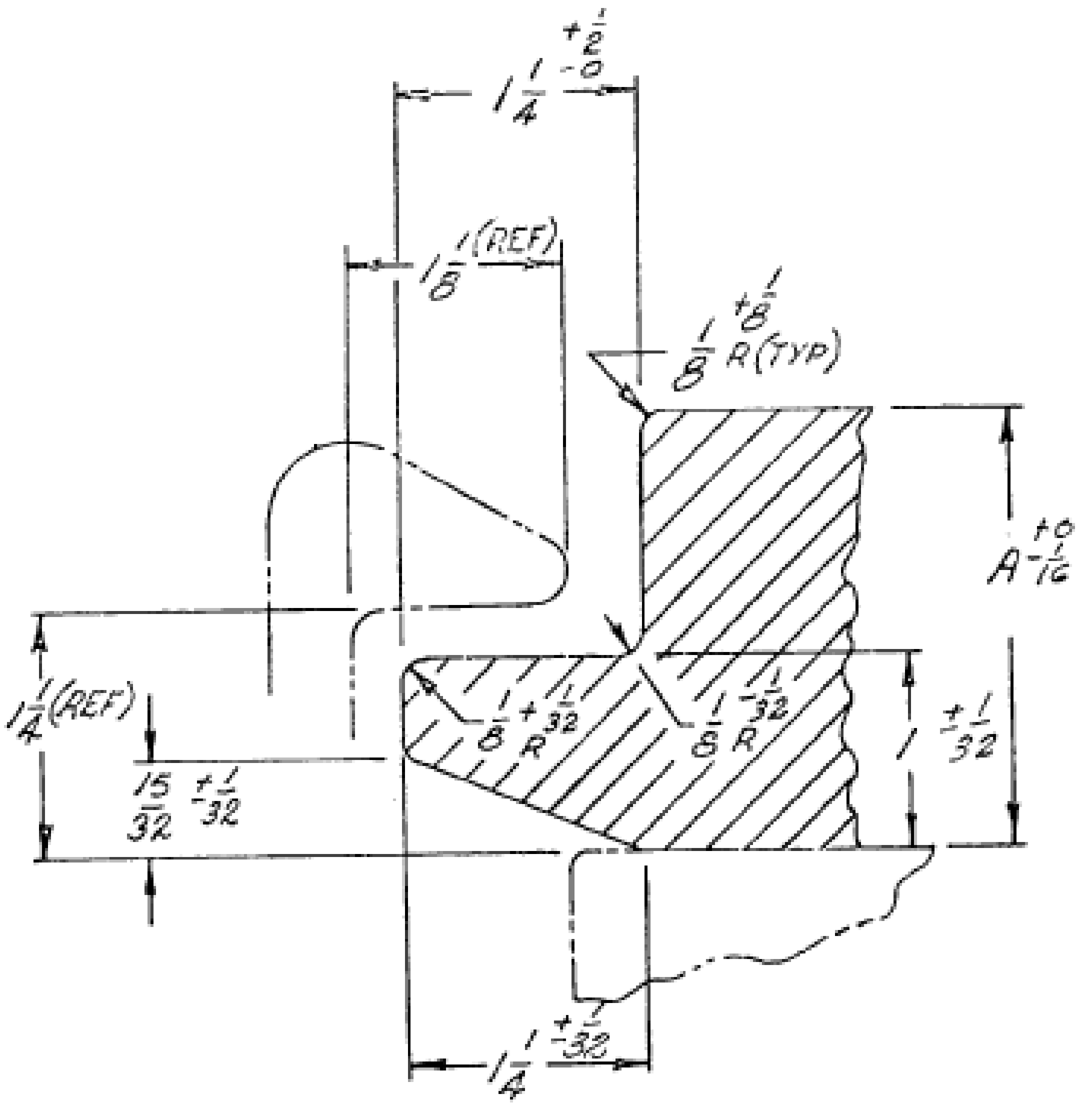

Figure 4.3 - Standard MIL-P-27443E (USAF)

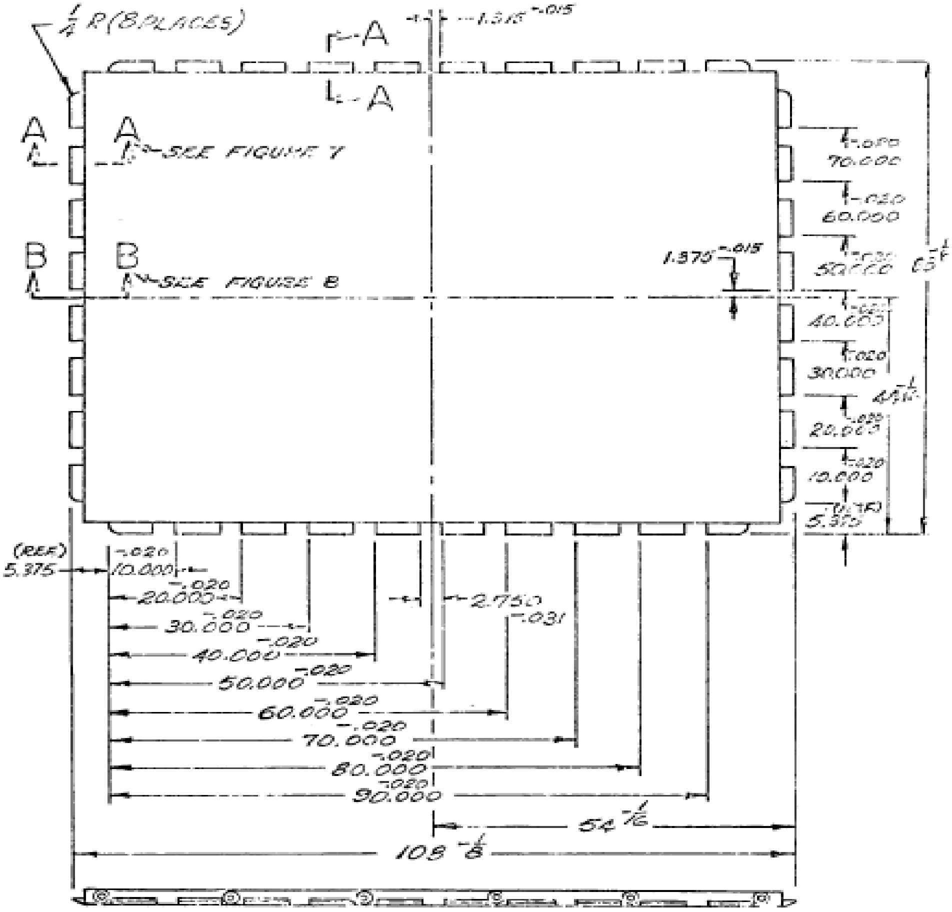

Figure 4.4 - Standard MIL-P-27443E (USAF)

Based on design considerations, it was decided to make the side lock profiles by the method of milling. The height of the profile is 43,5 mm.

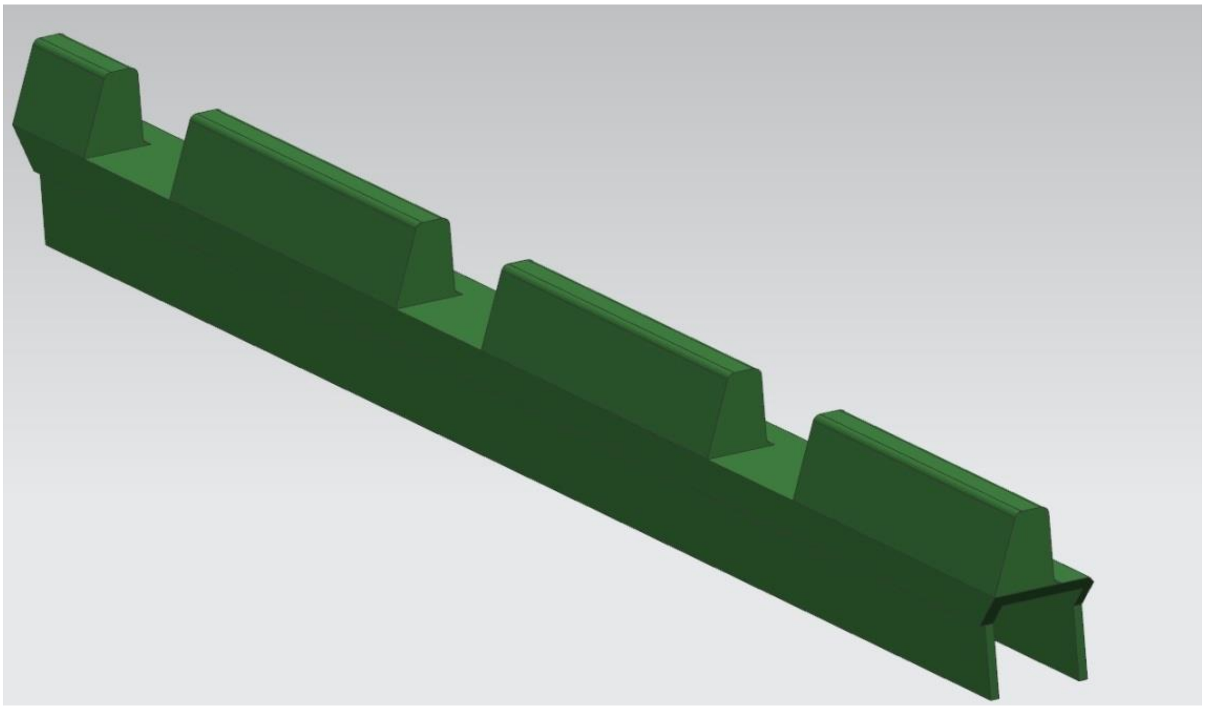

Figure 4.5 - Lock milled profile

As the power elements of the base of the thrust installation are I-beams (PK436-18, material D16), which are connected to the locking rails by means of a curved channel (PR106-2, material D16) at an angle of 90 degrees. The extreme I-beams are placed at the ends of the side profiles. The distance between the other three I-beams is 141 mm. Anchor nuts and bolts M6 are used by installation of fastening of details. The ends of the platform are closed by integral profiles made from material D16, which have a U-shaped protrusion and are fastened with M5 countersunk bolts.

As the upper and lower cladding is used material D 16 with thickness 2.5 mm. This thickness is due to the fact that the cladding is included in the power set and must be resistant to mechanical damage during operation of the product.

At the top of the platform are four brackets, two brackets for mounting braces and two brackets for fixing the thrust surface. The brackets are attached to the platform with M6 bolts. The brackets are made by milling (material D16T). The metal thickness of the bracket does not exceed 4 mm, but for the rigidity of the structure, between the horizontal planes are welded braces, two on each side. For greater contact with the locking pin, more metal is left on each side of the hole.

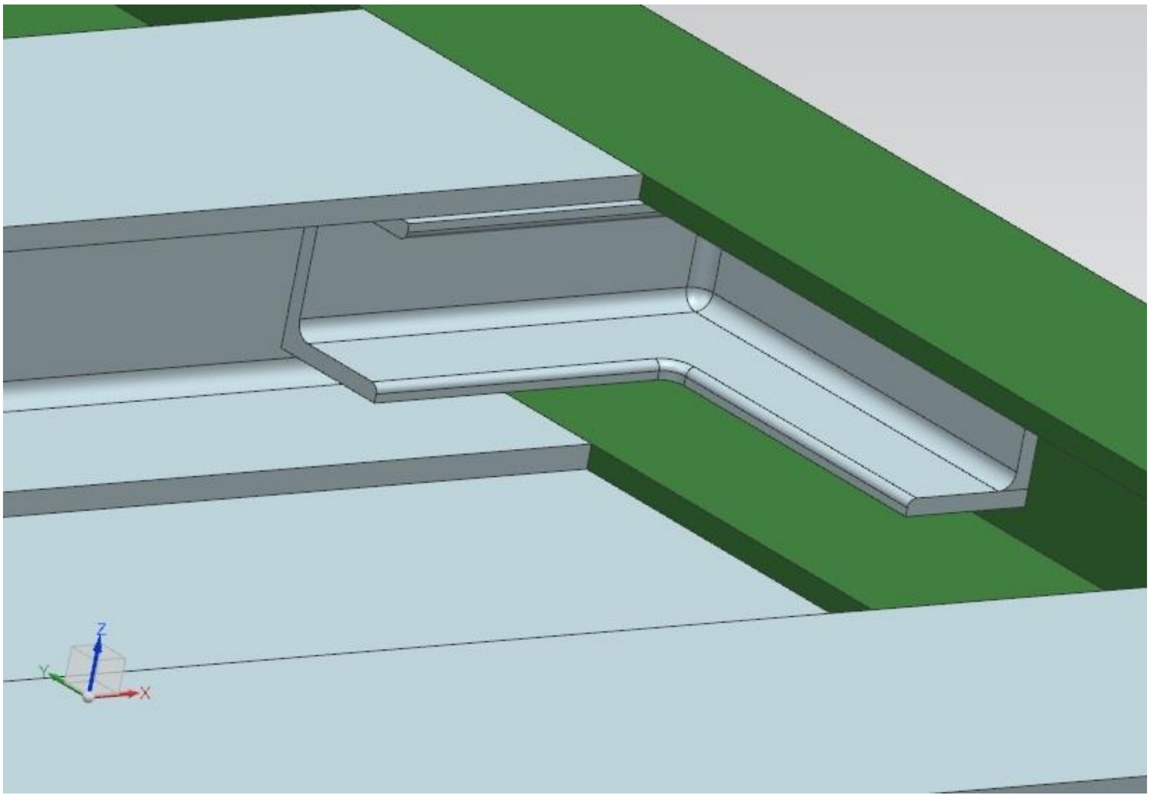

Figure 4.6 - Display the location of the curved channel in the base

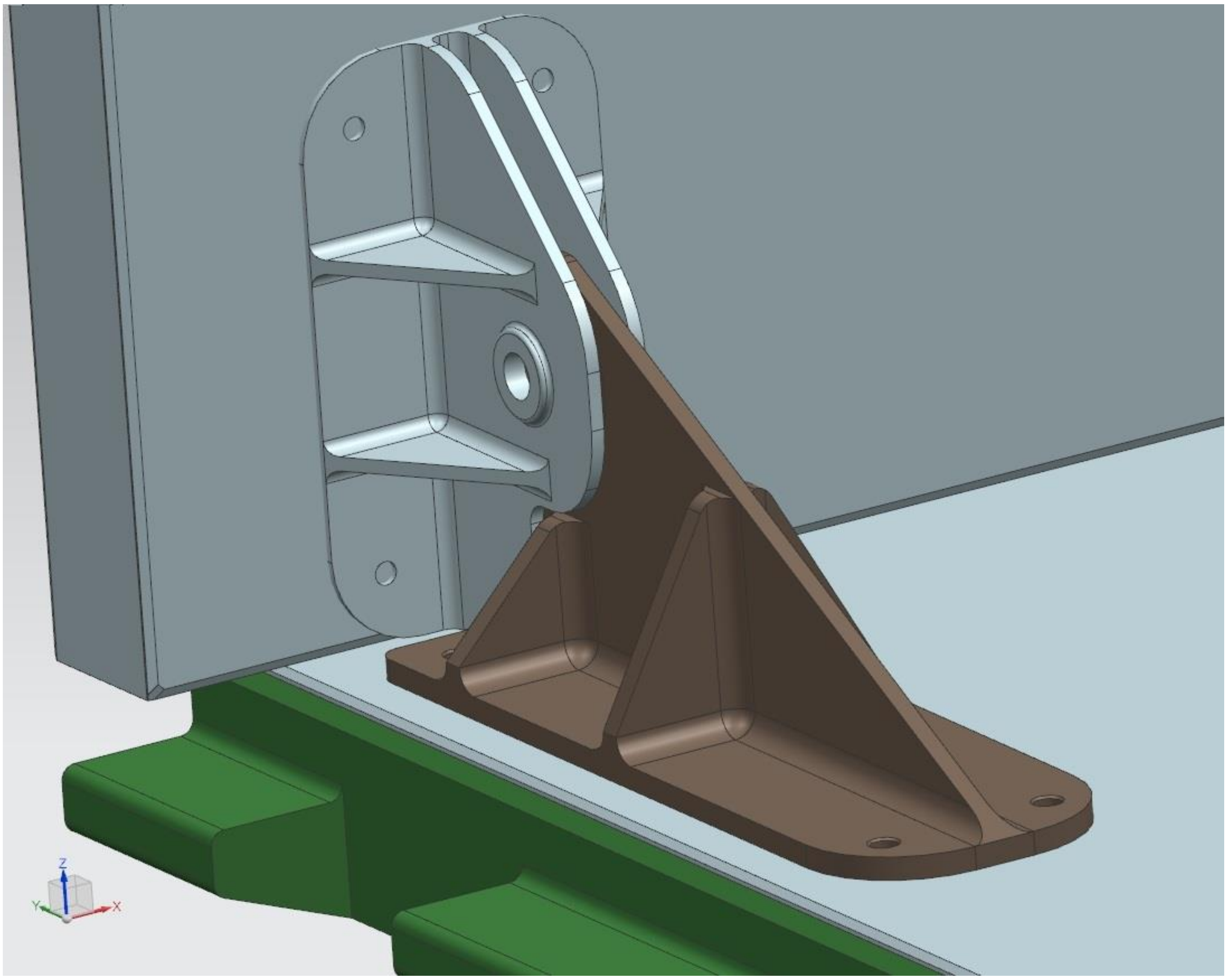

Figure 4.7 – Display the bracket connection

4.5.3 Development of a persistent wall

The main frame of the persistent wall surface consists of four identical channels, the dimensions of which are selected according to the range of profiles (PR106-34, material D16), which have a length of 1219,2 mm. Profiles (PR106-2, material D16) are interconnected by means of a bent channel at an angle of 90 degrees and form a square. Five I-beams (PK125-3) are mounted vertically in the middle of a framework by means of the bent channel (PR106-2) connecting a wall of an I-beam with a wall of a lateral profile. Anchor nuts with M6 bolts act as installation of fastening.

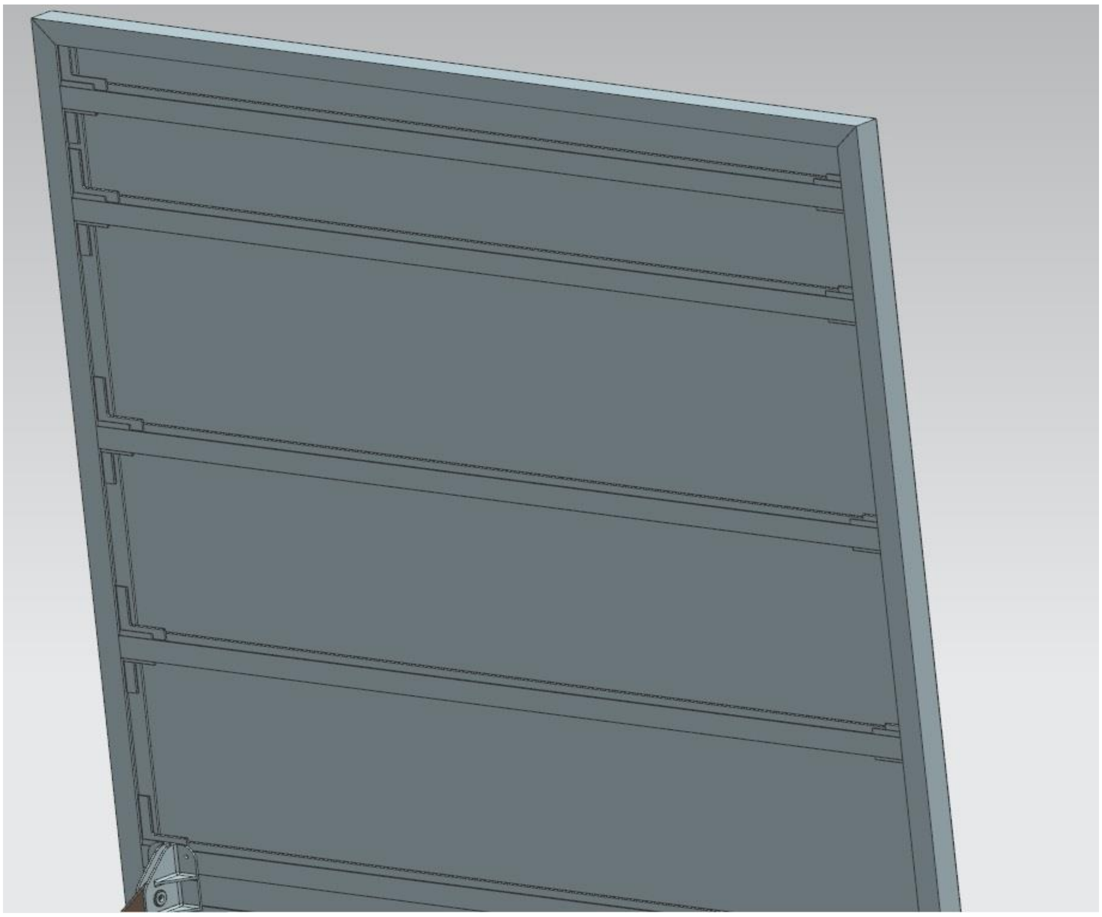

Figure 4.8 - The main frame of I-beams

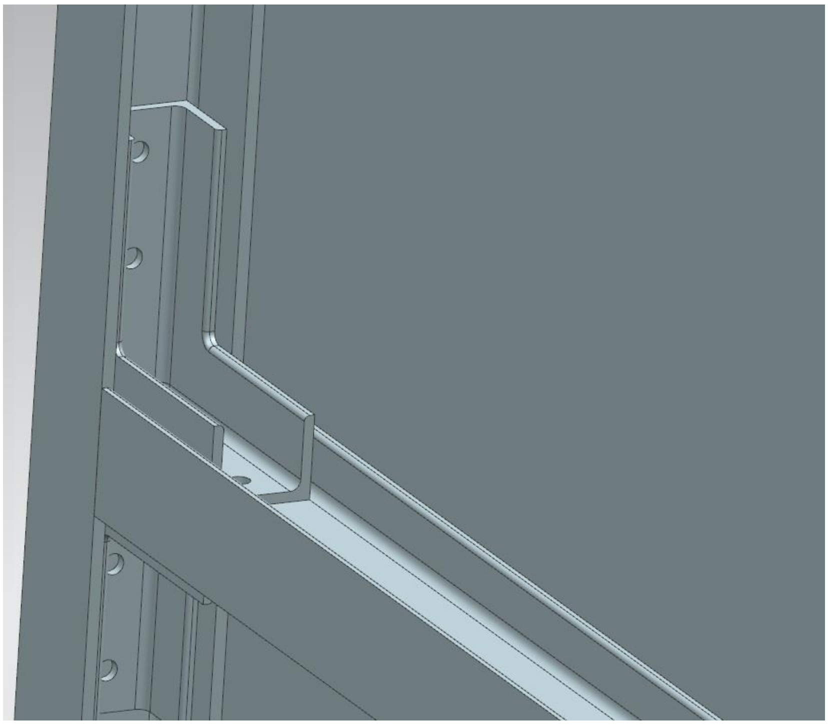

Figure 4.9 - Placement of a curved channel in the structure

The upper and lower I-beams are placed at a distance of 117 mm from the upper and lower profile, so that you can attach the brackets for supports and struts. The distance between the other three I-beams is 272.5 mm. The support bracket is made in the form of a fork, by milling (material D16), has four holes for fastening with M6 bolts to the I-beams. The technological feature of the bracket is a cut on the side planes, this is done in order to level down the persistent surface to the lower platform, without touching the bevels of the lower bracket.

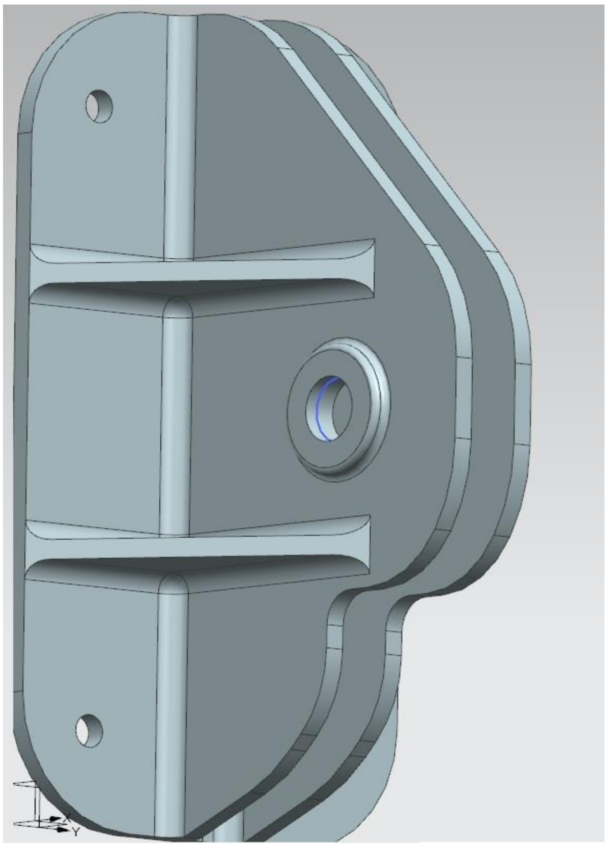

Figure 4.10 - Graphic image of the lower bracket

As the casing used material D-16 with thickness of 2,5 mm, fixed with rivets.

The brackets of the base and the persistent wall are connected by locking pins (OST 1 37029-80).

On the sides in the upper part of the persistent wall, special brackets (material D16) are installed. In them installation places are milled, for installation of a link with a spherical neck for which the mooring ring fastens. A bronze bushing is inserted into the installation places. The bracket is attached to the channel with hex bolts under the cover. Mooring belts are attached to the mooring ring, and due to the fact that the spherical link can rotate and move, the belt hook does not come into contact with the load.

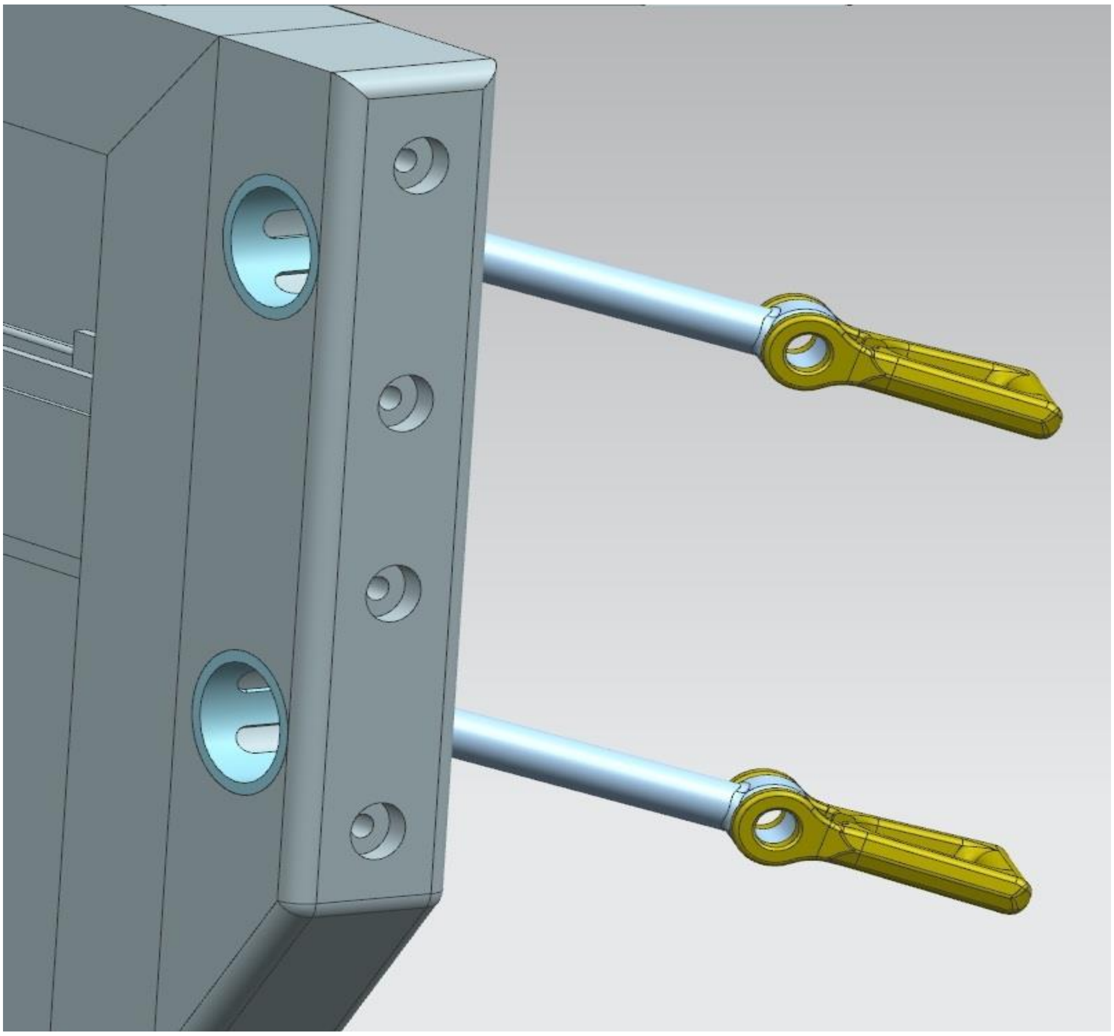

Figure 4.11 - Placement of a bracket with mooring rings

4.5.4 Development of struts

In order to keep the installation in the working position before the airdrop equipments are installed, as well as to partially transfer the load between the base and the persistent wall, struts are installed. Fastening of struts is carried out through brackets by pins with the fixing stopper according to OST 1 37032-80. D16T was chosen as the material of the struts.

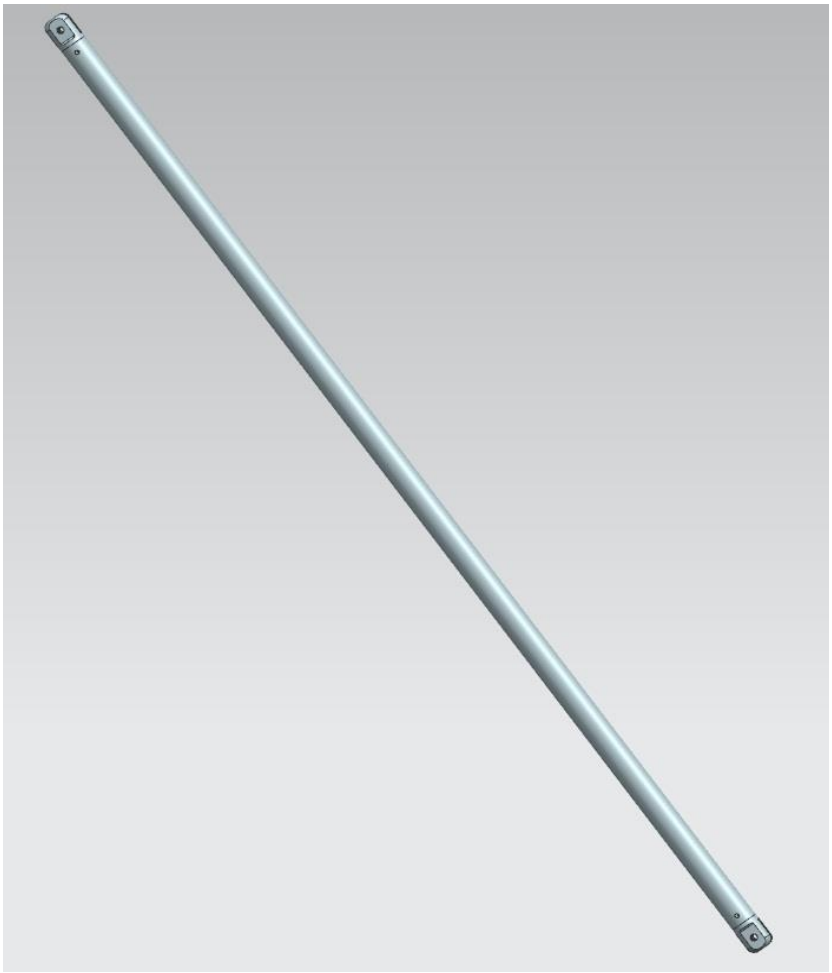

Figure 4.12 - Graphic image of strut

4.5.5 Mooring belts

Mooring belts are used to transfer the main load from the load to the mooring slots located on the cargo floor.

To simplify the design and reduce its weight and the number of pieces of equipment, mooring belts are taken from the set of standard mooring equipment of the aircraft.

Belts in the amount of 4 pieces with the ends on which the hooks are located, are attached to the spherical link on the thrust wall, and the other to the mooring of the shaft sockets on the floor of the aircraft.

Tension mechanisms are present on the belts to prevent sagging.

The general view of the mooring belt is shown in figure 4.13.

Figure 4.13 - General view of the mooring belt

Figure 4.14 – General view of buffer stop

4.6 Calculation of the stress-strain state of the nodes of the strut of buffer stop

Consider the place of attachment of the strut to the buffer stop and the base (Figure 4.15).

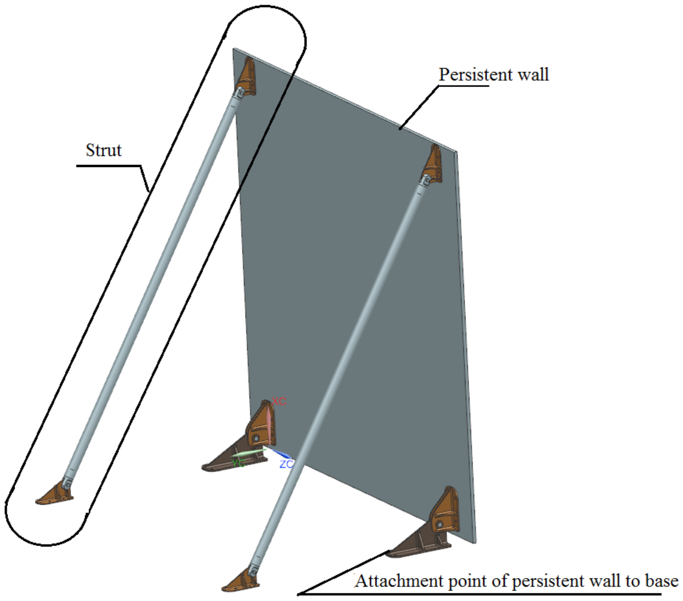

Figure 4.15 - General view of the buffer stop strut construction

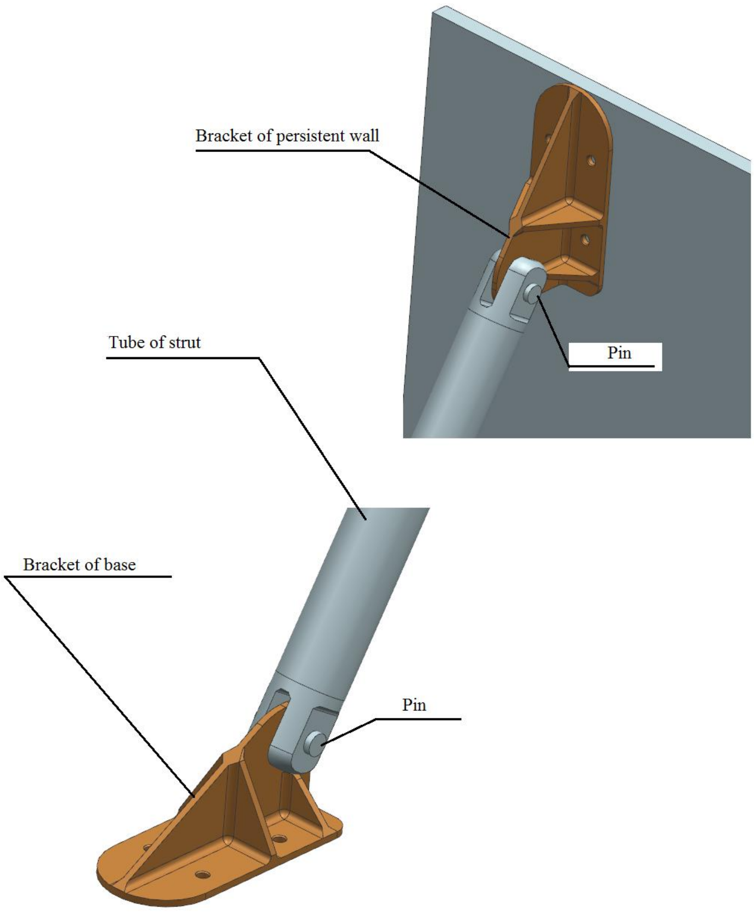

Figure 4.16 - General view of the strut elements

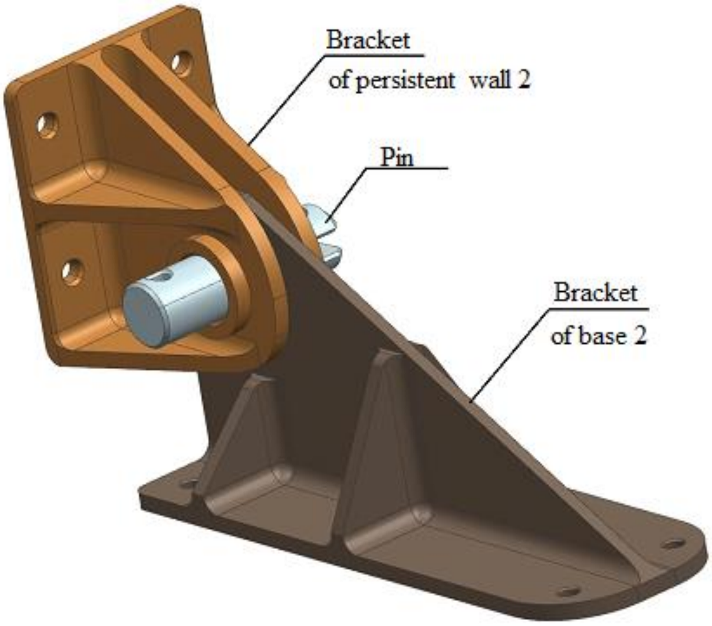

Figure 4.17 - Attachment of the stop to the base

The calculation of the stress-strain state is performed by using the module "NX Advanced Simulation".

To simplify the calculation model, all pins are represented by the element shown in figure 4.18.

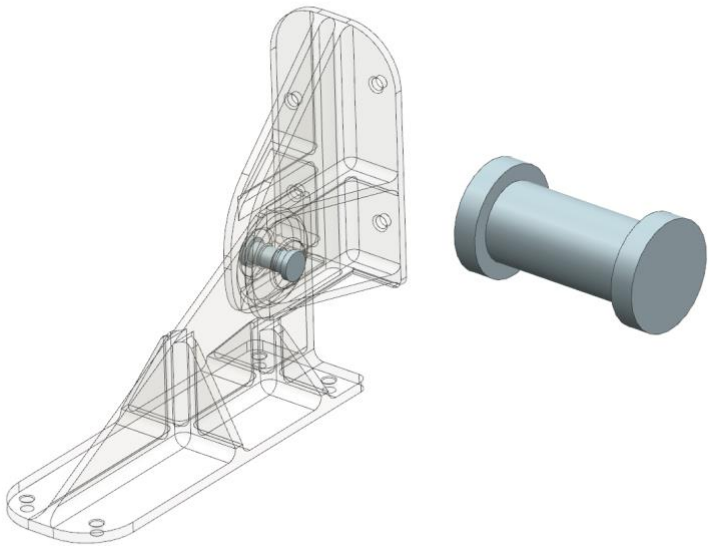

Figure 4.18 - Pin simulating element

Fixing the model in space. The basis bracket is fixed rigidly on the ends of four openings, in places of its fastening to the basis.

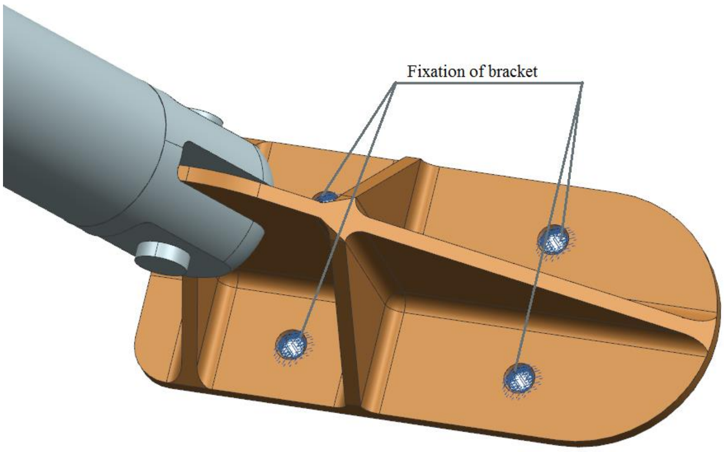

Figure 4.19 - Bracket mounting points

The basis bracket 2 is fixed rigidly on the ends of four openings, in places of its fastening to the basis.

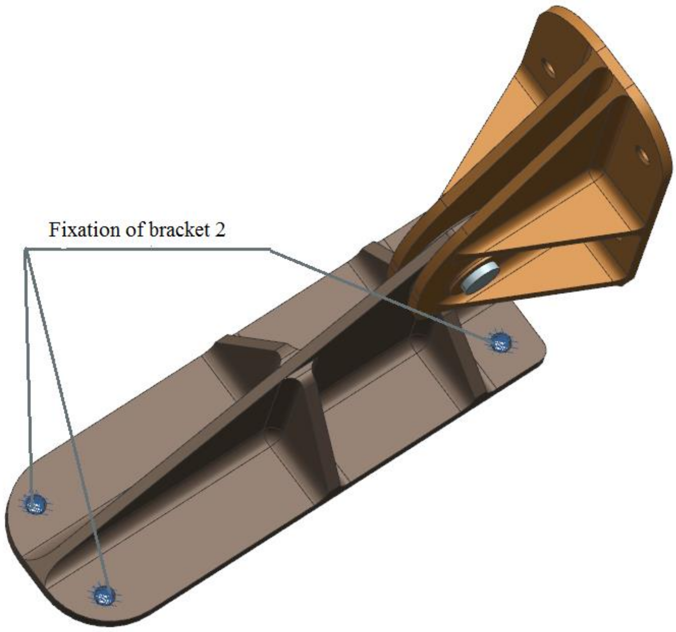

Figure 4.20 – Bracket 2 mounting points

Contact surfaces are created between all parts, through which the load is transmitted. The load is applied to the rear surface of the stop (Fig. 4.21). The load acts in the direction of flight of the aircraft. Cargo weight (gross) on a container is $G_{max} = 1102\ kgf$, number of containers N_{cont} is 10. Consider the calculation case with the highest overload $+n_x^{cal}$.

$$\begin{Bmatrix} n_x^{cal} = +2{,}05 \\ n_y^{cal} = -2{,}1..-4{,}5 \end{Bmatrix}$$

Calculation load is calculated according to formula:

$$P_x^{cal} = N_{cont} * G_{max} * n_x^{cal} = 10 * 1102 * 2{,}05 = 22591\ (kgf)$$

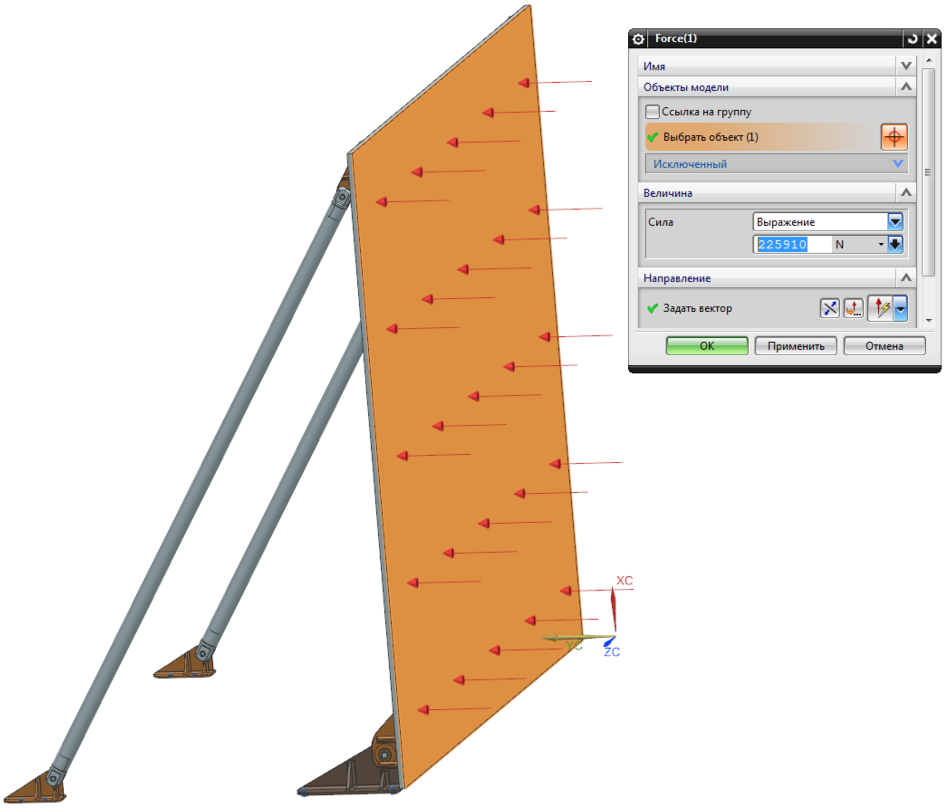

Figure 4.21 – Loading of installation

When creating a finite element model, the properties of materials are set. The smaller the size of the finite elements, the more accurate the results of the calculation.

Figure 4.22 - Finite element model

According to the calculation, the following data were obtained. Stress-strain state of the model is represented on figure 4.23.

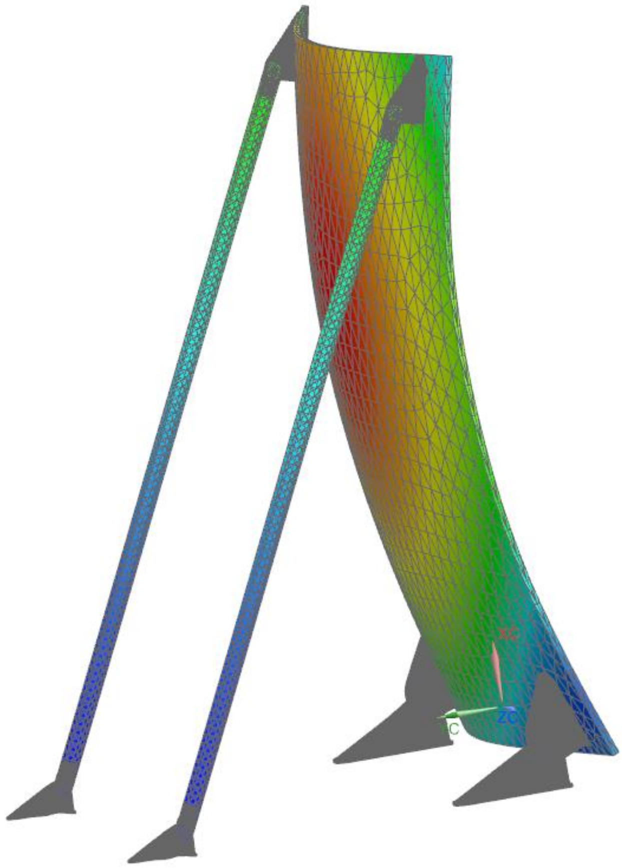

Figure 4.23 - Stress-strain state

Let's consider in more detail the stress-strain state of fastening of a strut to a basis.

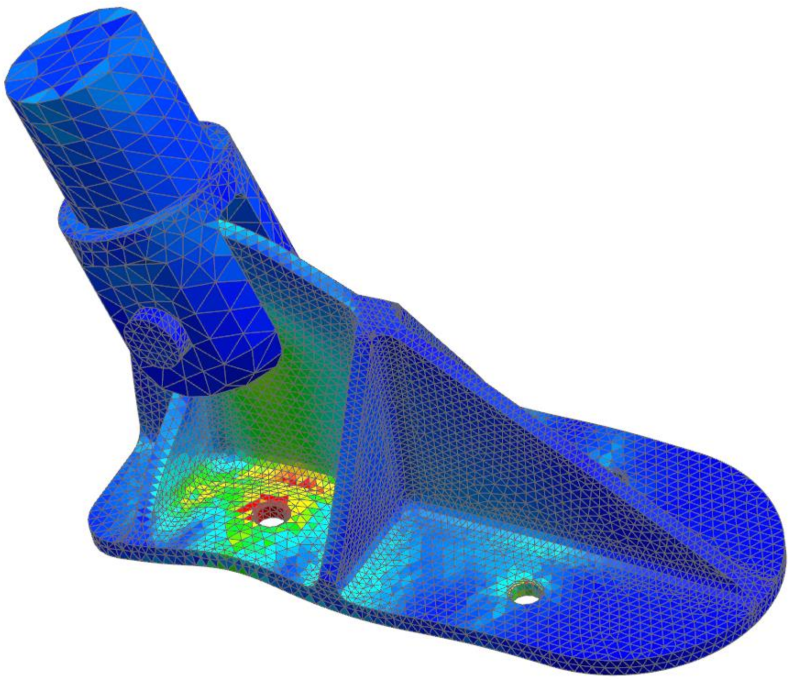

Figure 4.24 - Fastening of a bracket to a basis

For bracket of the bases was chosen material D-16T. Strength limit is equal to $\sigma_l = 4400\ kgf/cm^2$.

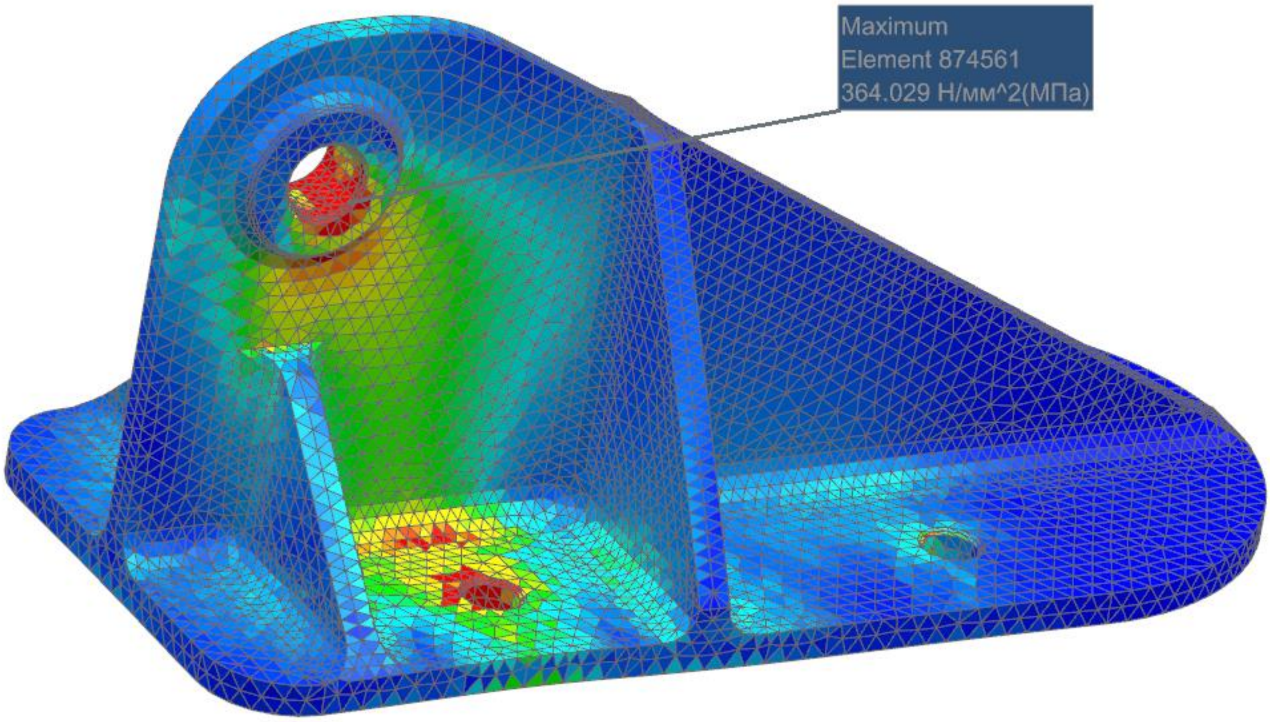

Figure 4.25 - Maximum loads of the bracket of base

The maximum equivalent stresses occurring in the bracket is equal to $\sigma_{eq}^{cal} = 364\frac{N}{mm^2} = 3640\ (\frac{kgf}{cm^2})$.

Safety factor coefficient is calculated according to next formula:

$$\eta = \frac{\sigma_l}{\sigma_{eq}^{cal}} = \frac{4400}{3640} = 1{,}22 \qquad (4.7)$$

Safety factor coefficient value satisfies safety demands.

For the pin was chosen material 30 ХГСА. Strength limit is $\sigma_l = 11000\ kgf/cm^2$.

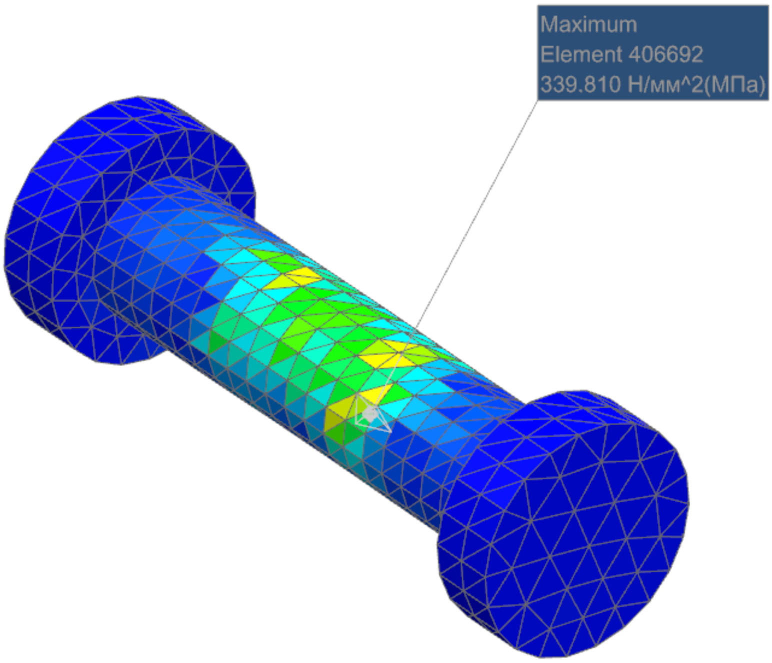

Figure 4.26 - Maximum pin loads

The maximum equivalent stresses occurring in the bracket is equal to $\sigma_{eq}^{cal} = 340 \frac{N}{mm^2} = 3400\ (\frac{kgf}{cm^2})$.

Safety factor coefficient is calculated according to next formula:

$$\eta = \frac{\sigma_l}{\sigma_{eq}^{cal}} = \frac{11000}{3400} = 3{,}2$$

Safety factor coefficient value satisfies safety demands.

Let's consider in more detail the stress-strain state of fastening of a bracket to the persistent wall of buffer stop.

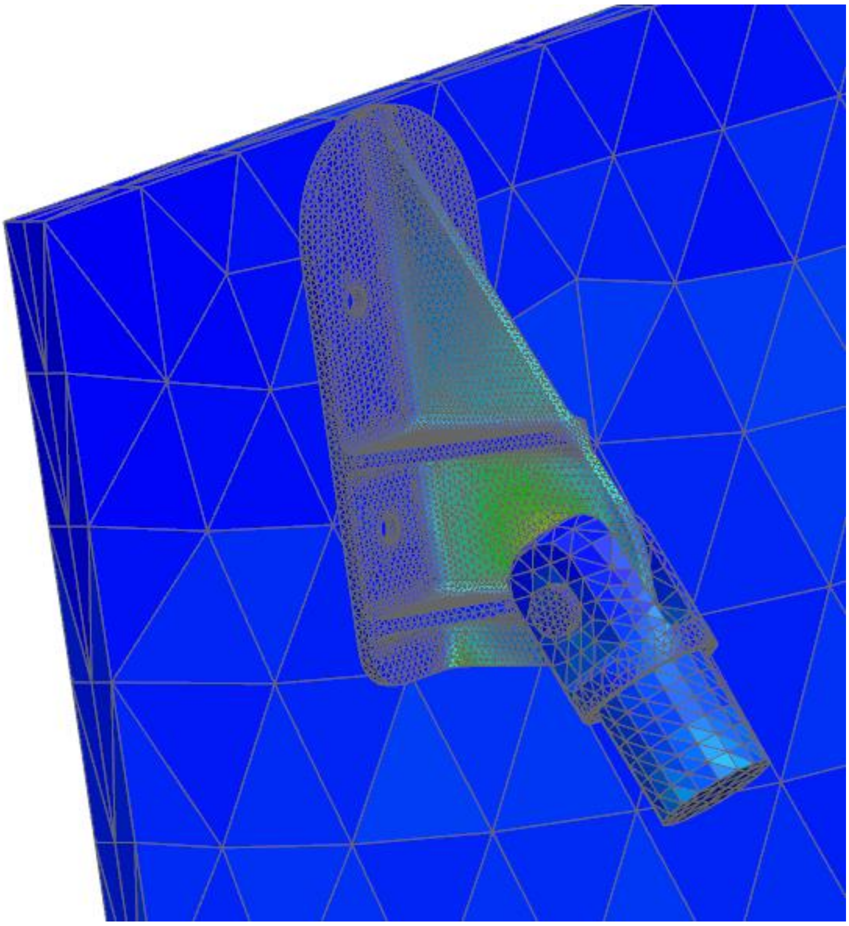

Figure 4.27 - Fastening of a bracket to the persistent wall

For bracket of the persistent wall was chosen material D-16T. Strength limit is equal to $\sigma_l = 4400\ kgf/cm^2$.

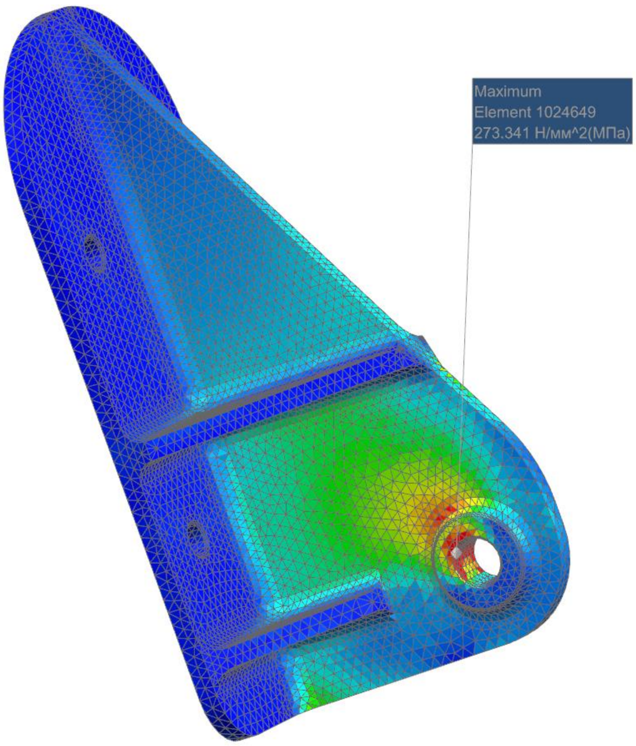

Figure 4.28 - Maximum bracket loads

The maximum equivalent stresses occurring in the bracket is equal to $\sigma_{eq}^{cal} = 273 \frac{N}{mm^2} = 2730 \left(\frac{kgf}{cm^2}\right)$.

Safety factor coefficient is calculated according to next formula:

$$\eta = \frac{\sigma_l}{\sigma_{eq}^{cal}} = \frac{4400}{2730} = 1{,}61$$

Safety factor coefficient value satisfies safety demands.

For the pin was chosen material 30 ХГСА. Strength limit is $\sigma_l = 11000\ kgf/cm^2$.

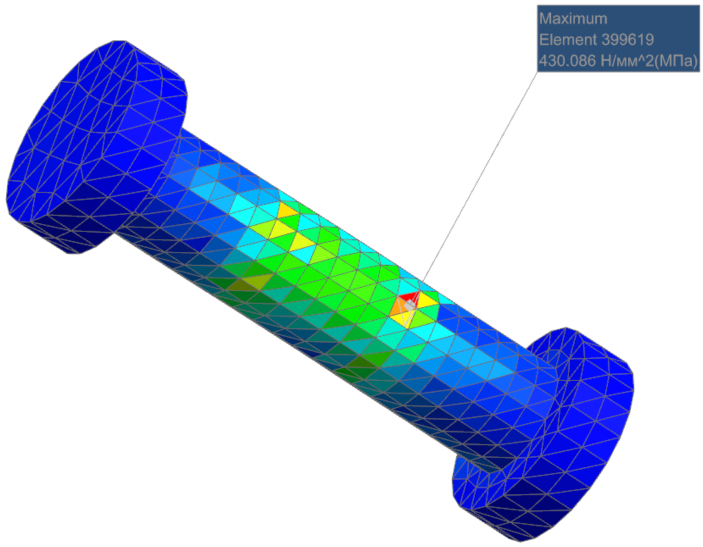

Figure 4.29 - Maximum pin loads

The maximum equivalent stresses occurring in the bracket is equal to $\sigma_{eq}^{cal} = 430 \frac{N}{mm^2} = 4300 \left(\frac{kgf}{cm^2}\right)$.

Safety factor coefficient is calculated according to next formula:

$$\eta = \frac{\sigma_l}{\sigma_{eq}^{cal}} = \frac{11000}{4300} = 2{,}6$$

Safety factor coefficient value satisfies safety demands.

Taking into account all the above data, we conclude that the static strength of the designed structural elements is sufficient.

Conclusion to the part 4

1. In this part it was studied parachute platforms and containers characteristics, their purpose and construction. Container of type A-22 was chosen as element for container delivery system due to it suitable performances for given system, which has next characteristics: width and length is 1219,2 mm, height is 25,4 mm, load weights are from 501 to 2200 lbs. Also it was calculated center of gravity of one load installed on container with full airborne equipment used during process of cargo airdrop by using gravity method.

2. Two calculation cases were reviewed: airdrop of army shells and airdrop of devices with provisions. For dissipation force act on airdrop device during contact with ground paper honeycombs can be used. So centers of gravity of airdrop device were calculated considering use of minimum and maximum rows of honeycombs. Center of gravity of container for the first calculation case is in the range from 583,7 mm to 877 mm; for the second calculation case is in the range from 685,5 mm to 976,7 mm. It is necessary to obtain these values for correct layout of containers on board of aircraft.

3. Then it was determined main requirements for buffer stop installation for subsequent development of its construction. What is more, buffer stop was developed taking into account MIL standards, aircraft cargo cabin construction specific, analyze of prototypes construction.

4. Calculation of the stress-strain state of the nodes of the strut of buffer stop was performed by using the module "NX Advanced Simulation". After calculation it was obtained next values of equivalent stresses acting on installation: for bracket of a basis - $\sigma_{eq}^{cal} = 3640\ \mathrm{kgf/cm^2}$, for pin - $\sigma_{eq}^{cal} = 3400\ \mathrm{kgf/cm^2}$, for bracket of the persistent wall - $\sigma_{eq}^{cal} = 2730\ \mathrm{kgf/cm^2}$, for pin - $\sigma_{eq}^{cal} = 4300\ \mathrm{kgf/cm^2}$. Also it was determined safety factor coefficient for each element of strut: for bracket of a basis - $\eta = 1{,}22$, for pin - $\eta = 3{,}2$, for bracket of the persistent wall - $\eta = 1{,}61$, for pin - $\eta = 2{,}6$. It can be concluded that the static strength of the designed structural elements is sufficient.

5 OCCUPATIONAL SAFETY

5.1 Analysis of harmful and dangerous production factors

According to the theme of my diploma project “Development of elements of a system for aerial cargo delivery by the gravity method”, I choose design of aircraft elements with the help of computer programs as operational procedure.

The process of designing aircraft at this stage of development of information technologies is carried out with the use of computer technology, which is associated with harmful effects on the human body, which is in the immediate vicinity of a computer.

In the process of performing work, the design engineer may be affected by the following hazardous and harmful production factors according to the standard ГОСТ 12.0.003-74:

1. Factors which belong to physical harmful factor
- a dangerous voltage level in an electrical circuit, the short circuit of which can occur through the human body (when working with a PC, lighting devices, household appliances, a printer, a scanner and other types of office equipment)
- increased level of electromagnetic radiation (when working with a PC);
- an increased level of static electricity (when working with a PC);
- reduced air ionization (when working with a PC);
- increased noise level (when working with a PC);
- irrational organization of the workplace;
- insufficient illumination of the working area.
2. Factors which belong to psychophysiological harmful factor
- increased nervous stress;
- psycho-emotional stress, overwork.

5.1.1 Requirements for the area of the workplace

Workplaces are designed taking into account the average anthropometric data of a person. When an engineer is working at a table, the design of the table and chair should provide an optimal comfortable position for the human body. According to SSanRIN 3.3.2.007-98 “State sanitary rules and norms of work with visual display terminals of electronic computers” the distance from the floor to the table surface should be 0.75 m for man and 0.7 m for women, the seat height - 0.42 m both for man and women, the height of the leg opening - 0.6 m, the opening depth - 0.5 m. Naturally, these values are averaged and for different people they are will be different.

The dimensions of the area where the development took place are:

- length 6 m;
- width 5 m;
- height 4 m.

Based on these dimensions, the area of the room is 30 m^2, and the volume is 120 m^3. The room is equipped with 4 workers, which meets the sanitary standards. The area allocated for one workplace with a video terminal or personal computer must be at least 6 square meters, and the volume must be at least 20 cubic meters.

5.1.2 Workplace illumination requirements

High demands are placed on modern lighting, both hygienic and technical and economic. Rational lighting of the workplace is one of the most important factors in preventing injuries and occupational diseases. Properly projected lighting ensures high levels of operability and increases productivity. The importance of this issue is evidenced by the fact that the conditions of the designer's activity are associated with the predominance of visual information - up to 90% of the total volume.

Natural lighting is characterized by the fact that the generated illumination varies over an extremely wide range. These changes are due to the time of day, year and meteorological factors: the nature of the cloudiness and the reflective properties of the land cover. Therefore, natural lighting cannot be quantitatively specified by the amount of illumination.

As a normalized value for natural lighting, a relative value is taken - the coefficient of natural illumination (CNI), which is a percentage ratio of the illumination at a given point inside the room E_{in} to the simultaneous value of the external horizontal illumination E_{out}, created by the light of a completely open sky. Thus, CNI assesses the size of window openings, the type of glazing and sashes, their contamination, that is, the ability of the natural lighting system to transmit light.

According to the current sanitary norms and rules “State building norms of Ukraine SBN B.2.5.28-2018. Natural and artificial lighting”, the lowest permissible illumination is regulated for artificial lighting, and CNI is determined for natural and combined. Illumination standards are based on the classification of visual work according to certain quantitative criteria. The leading feature that determines the grade of work is the size of the distinguishable parts. In turn, the categories are divided into 4 sub-categories, depending on the background light emission and the contrast between the details and the background. Illumination rates depend on the adopted lighting system. So, with combined artificial lighting, the norms are higher than with ordinary ones. Quantitative indicators are also normalized: to limit the adverse effects of pulsating light fluxes of gas-discharge lamps, the limiting values of the pulsation coefficients are set (depending on the category of visual work).

The recommended illumination for working with the display screen is 200 lux, and when working with the screen in combination with work with documents 400 lux. The recommended brightness in the operator's field of view should be in the range 1: 5 ... 1:10.

Natural light requirements:

1) The coefficient of natural light for industrial premises with visually stressful work should be in accordance with SBN B.2.5.28-2018:

- 0.035 (3.5%) - with one side illumination for the highest accuracy;
- 0.025 (2.5%) - with one side lighting for high precision work;
- 0.020 (2%) - with side lighting for high precision work.

2) Light openings of industrial premises should be oriented to the north, in addition, sun protection devices (blinds, canopies, screens, curtains, frosted glass, etc.) should be provided to eliminate the glare of sunlight in the workplace.

In the current norms for the design of industrial lighting SBN B.2.5.28-2018, both quantitative (the value of the minimum illumination) and qualitative characteristics (the indicator of glare and discomfort, the depth of the pulsation of illumination) of artificial lighting are specified.

The value of the maximum illumination is set according to the characteristics of visual work, which is determined by the smallest size of the object of discrimination, the contrast of the object with the background and the characteristics of the background. There are eight categories and four sub-categories of work, depending on the degree of visual stress.

When determining the illumination rate, one should also take into account a number of conditions that necessitate an increase in the illumination level selected for the accuracy of visual work. Increased illumination, for example, with an increased risk of injury or when performing intense visual work of 1-4 categories throughout the working day (visual inspection of products, marking on sheet metal). In some cases, the illumination rate should be reduced, for example, when people are in the room for a short time. Separate standardization of illumination is adopted depending on the used light sources and lighting system.

Requirements for artificial lighting:

1) Illumination of the working surface with combined (general and local) lighting must comply with the standards, illumination of workplaces with general lighting in the combined system must be no higher than 500 and no less than 150 lux.

2) Illumination of workplaces in industrial buildings without natural lighting must comply with SBN B.2.5.28-2018:

- not less than 300 lx - for operation of I and II categories;
- not less than 200 lx - for work of the III and IV categories.

5.1.3 Analysis and requirements for noise level

From a physiological point of view, noise is considered as a sound that interferes with spoken language and negatively affects human health. Noise is one of the most common harmful factors in production. People working in conditions of increased noise complain of fatigue, headache, and insomnia. A person's attention is weakened, memory suffers. All this leads to a decrease in labor productivity. Noise in workplaces is created by operating equipment and also comes from outside.

This standard applies to machines, processing equipment and other noise sources that create all types of noise in the air in accordance with sanitary norms of industrial noise, ultrasound and infrasound SSN 3.3.6.037-99.

The noise level from computers and other equipment used in the development is negligible. In this particular case, its level is determined only by human economic activity and is 40 dB, which corresponds to the standards defined by the above-mentioned SSN.

To assess noise, use the frequency spectrum of the measured sound pressure level, expressed in dB, in octave frequency bands, which is compared with the limiting spectrum, are given in the table 5.1.

Table 5.1 - Standard values according to state sanitary norms

Type of work, workplaces	Sound pressure levels, dB, in octave bands with geometric mean frequencies, Hz									Sound levels and equivalent sound levels, dB A
	1.5	3	25	50	00	000	000	000	000	
Creative activity, design and engineering. Workplaces in the rooms of design bureaus.	6	1	1	4	9	5	2	0	8	50

During the process of performing work, in my opinion workplace illumination is one the most significant factor which impact on the health of design engineer. Due to lack of sufficient lighting, productivity of design engineer decreases.

5.2 Measures to reduce the impact of harmful and dangerous production factors

One of the most important hygienic indicators of a workplace is room illumination. The work area or workplace is illuminated to such an extent that it is possible to clearly see the work process without straining the eyes, and it is excluded that the rays of the light source directly enter the eyes. In addition, the level of illumination is determined by the degree of accuracy of visual work. According to the lighting standards SBN B.2.5.28-2018 and industry standards, the work of an engineer belongs to the fourth category of visual work.

The main task of lighting calculations is to determine the required area of light openings in natural lighting and the power consumption of lighting devices in artificial lighting.

The required area of the light opening for lateral natural illumination is determined by the formula (5.1) :

$$S = \frac{S_n * e_N * K_s * \eta_0 * K_d}{100 * \tau_0 * r_1} \tag{5.1}$$

where, S_r - is the area of the room, m^2; e_N - normalized value of CNI,%; K_s - safety factor taken from tables; η_0- light characteristic of windows (6,5 - 29); K_d - coefficient taking into account the darkening of windows by opposing buildings (1,0 – 1,7); r_1 is the coefficient taking into account the increase in CNI due to reflected light from the surface of the room (1,05 – 1,7); τ_o - general coefficient of light transmission, determined from SNaR 11-4-79 (0,1 – 0,8).

The area of the room is S_r=6*5=30 m^2. The normalized CNI is determined as e_N=1,5. Safety factor coefficient is taken as K_s=1,5.

The value of the remaining coefficients is assumed to be the following:

The ratio of the length of the room to its depth is 1.2, the value of the light characteristic with the ratio of the depth of the room to its height from the level of the conventional working surface to the top of the window is 1.5, so from table choose value of light characteristic of windows η_0= 15.

Choose from table value of coefficient taking into account the darkening of windows by opposing buildings K_d= 1.1

Choose from table value of the coefficient taking into account the increase in CNI due to reflected light from the surface of the room r_1 = 1,05.

General coefficient of light transmission is calculated according to formula (5.2):

$$\tau_o = \tau_1 * \tau_2 * \tau_3 * \tau_4 * \tau_5 \quad (5.2)$$

where, τ_1- the coefficient of light transmission of the material, determined by table. For double sheet glass τ_1=0.8; τ_2 -coefficient taking into account the loss of light in the bindings of the aperture, determined from the table. Binders for windows and lamps of industrial buildings, steel, single open, τ_2=0.75; τ_3 - coefficient that takes into account the loss of light in the bearing structures, determined from the table. With lateral lighting τ_3 = 1; τ_4 - coefficient taking into account the loss of light in sun protection devices for retractable adjustable blinds and curtains, τ_4=1; τ_5 - coefficient taking into account the loss of light in the protective grid, installed under the lantern is taken equal to 0.9.

Calculate coefficient according to formula (5.2):

$$\tau_o=0,8*0,75*1*1*0,9=0,54$$

So, when calculating according to formula (5.1), we get the following value of the required area:

$$S = \frac{30 * 1,5 * 1,5 * 15 * 1,1}{100 * 0,54 * 1,05} = 19,6 \ (m^2)$$

Considering that the area of the window opening in the room is about S=3,3*6=19,8 m^2, the use of one side lighting is enough for this room.

5.3 Occupational safety instruction

5.3.1 General safety requirements

The design engineer informs his immediate supervisor about any situation that threatens the life and health of people, about every accident that occurs at work, about the deterioration of his health, including the manifestation of signs of an acute illness.

While on the territory and in the buildings of the organization, at the work sites and workplaces, the design engineer is obliged to:

- timely and accurately comply with the internal labor regulations, orders of the immediate supervisor, provided that he is trained in the rules for the safe performance of this work;
- comply with the requirements of local regulations on labor protection, fire safety, industrial sanitation, regulating the procedure for organizing work at the facility;
- observe labor discipline, work and rest regime;
- take good care of the employer's property.

5.3.2 Safety requirements before starting work

Before starting work enginner should perform following safety requirements:

- Inspect the workplace and equipment.
- Remove all unnecessary items.
- Remove dust from the display screen of a personal computer.
- Adjust the height and angle of the screen.
- Adjust the seat height.
- Check the health of the equipment.
- Check approaches to the workplace, escape routes for compliance with labor protection requirements.

Check by visual inspection:

- absence of cracks and chips on the cases of sockets and switches, as well as the absence of bare contacts;
- reliability of closing all current-carrying devices of the equipment;

− presence and reliability of grounding connections (absence of breaks, strength of contact between metal non-current-carrying parts of the equipment and the grounding wire);

− the integrity of the insulation of electrical wires and power cords of electrical appliances, the serviceability of safety devices;

− sufficiency of lighting of the workplace;

− absence of foreign objects around the equipment;

− condition of floors (absence of potholes, irregularities, etc.).

5.3.3 Safety requirements during operation

During work enginner should perform following safety requirements:

− Use serviceable equipment, fixtures, lighting devices necessary for safe work, use them only for those works for which they are intended.

− Monitor the equipment operation, periodically carry out its visual preventive inspection.

When working with a PC:

− the screen should be 5 degrees below eye level, and be located in a straight plane or tilted towards the operator (15 degrees);

− the distance from the eyes to the screen should be within 60-80 cm;

− the local light source in relation to the workplace should be located so as to exclude direct light from entering the eyes, and should provide uniform illumination on a surface of 40 x 40 cm, not create blinding glare on the keyboard and other parts of the console, as well as on the video terminal screen in direction of the eyes;

− to reduce visual and general fatigue, after each hour of working at the screen, you should use regulated breaks of 5 minutes, during which you take rest.

5.3.4 Safety requirements after work

After work enginner should perform following safety requirements:

− Switch off the equipment during a power outage and leaving the workplace after work.

− Inspect the workplace and equipment.

− Remove all unnecessary items.

– Check by visual inspection equipment on lack of defects.

5.3.5 Safety requirements at emergency situations

When eliminating an emergency, it is necessary to act in accordance with the approved emergency response plan.

Upon detection of malfunctions of equipment, instruments and apparatus, as well as in the event of other conditions that threaten the life and health of workers, the design engineer should stop work and report them to his immediate supervisor and the employee responsible for the implementation of production control.

When a fire source appears, you must:

- stop working;
- turn off electrical equipment;
- organize the evacuation of people;
- start extinguishing the fire immediately.

When electrical equipment catches fire, use only carbon dioxide or dry powder fire extinguishers.

If it is impossible to carry out extinguishing on his own, the design engineer should, in accordance with the established procedure, call the fire brigade and inform the immediate supervisor about it.

In the event of injury or deterioration of health, the design engineer must stop work, notify the management and seek medical help.

Conclusion to the part 5

In this part of diploma work were defined main hazardous and harmful production factors according to the standard which affected on the design engineer during performing work. Then it was determined following the most significant factors, which influence on engineer: area of the workplace, workplace illumination, noise level at the workplace area. According to state standards, it was studied requirements to permitted values of chosen factors and checked for compliance with these standards workplace of engineer. Based on these dimensions, the area of the room is 30 m^2, and the volume is   120 m^3. The room is equipped with 4 workers, which meets the sanitary standards.

One of the most important hygienic indicators of a workplace is room illumination. The work area or workplace is illuminated to such an extent that it is possible to clearly see the work process without straining the eyes, and it is excluded that the rays of the light source directly enter the eyes. Due to this fact it was calculated required area of the light opening for lateral natural illumination and this value is equal to $S = 19.6\ m^2$. Then it was considered that the area of the window opening in the workplace of engineer is about S=19.8 m^2, the use of one side lighting is enough for this room.

What is more, it was proposed general safety rules for design engineer, which worker should carry out before, during and after working day and also at emergency situations.

6 ENVIRONMENTAL PROTECTION

The impact of aircraft on the atmosphere is determined by the level of its pollution due to the emission of harmful substances from the exhaust gases of aircraft engines.

Aircraft move from one airport to another during the flight, and the atmosphere is polluted on a global scale, significant pollution occurs both in the areas of airports and on the routes of flight. Moreover, if on the flight paths (at an altitude of 8-12 km) the danger of this pollution is small (flights of aircraft at high altitudes and at high speeds cause the scattering of combustion products in the upper atmosphere and large areas, which reduces their impact on living organisms), in the airport area cannot be considered such pollution is impossible [14].

Gases are emitted into the atmosphere by engine nozzles and exhaust pipes, which is defined by the term "aircraft engine emissions".

Gases generated by aircraft engines account for 87% of all civil aviation emissions, which also include emissions from special vehicles and stationary sources [14].

The most unfavorable modes of operation are low speeds and idling of the engine, when pollutants are emitted into the atmosphere in quantities significantly exceeding the emission at load modes.

The main components of exhaust gases of modern aircraft engines that pollute the atmosphere are:

- sulfur oxides SO_x;
- nitrogen oxides NO_x;
- carbon monoxide CO.

During the take-off of an aircraft, approximately 50% of emissions in the form of microparticles, including many heavy metals, are immediately dissipated in areas adjacent to the airport. The rest is in the air for several hours in the form of aerosols, and then also settles on the ground.

Each engine developed (for aircraft) undergoes a series of tests (certification) before being put into series production, including environmental safety research, so the

International Civil Aviation Organization (ICAO) has developed strict emission standards for aircraft engines.

Carbon monoxide CO has no color or odor and is one of the biggest air pollutants. It is formed during incomplete combustion of fuel. At concentrations in the air of more than 1%, it has a negative effect on plants, animals and humans, more than 4% - causes the death of organisms. The toxicity of carbon monoxide is its ability to prevent red blood cells from retaining oxygen, resulting in oxygen starvation of the body, which can lead to death [14].

Nitrogen oxides (N_2O, NO, NO_2, N_2O_3, N_2O_5) are 10 times more dangerous for humans than CO. They are formed due to imperfect fuel combustion technology. They also cause acid rain. When combined with water in the respiratory tract, they form nitric acid, which causes severe irritation of the mucous membranes and severe disease. They are also absorbed by the leaves of plants, which then lose forage and get sick [14].

6.1 Calculation of the emissions of CO and NO_x from aircraft engine and the emissions of CO and NO_x from aircraft at the zone of airport per year

Emissions of CO and NO_x at the airport zone are calculated for takeoff and landing cycle. Characteristics of regimes and their duration are given in table 6.1.

Table 6.1 - The typical takeoff and landing cycle of aircraft engine power conditions

Number of regime	Characteristics of regimes	Relative thrust $\overline{R}$	Duration of regime t, min
1	Start, idle running before takeoff (regime of low gas)	0,07	15,0
2	Takeoff	1,0	0,7
3	Climb	0,85	2,2
4	Approach landing from a height of 1000 m	0,3	4,0
5	From landing taxiing (regime of low gas)	0,07	7,0

Table 6.2 - Emission indexes of CO and NO_x during ground operations with different aircraft engine types (kg of detrimental compound / kg of fuel)

Type of aircraft	Maximal thrust of engine R_0, kN	Type of aircraft engine	Quantity of engines n	$C_{SP\ LG}$, kg/N·hour	Emission index k	
					CO	NO_2
АН-178	80	Д-436-148ФМ	2	0,049	0,0546	0,0054

Table 6.3 - Weight rate of CO and NO_x emissions by different aircraft types

Type of aircraft	Annual quantity of flights ***N***	Relative thrust $\overline{R}$ of regimes 2, 3, 4 relatively	Weight rate of emissions W, kg/hour	
			CO	NO_2
АН-178	100	1 0,85 0,3	6,0 7,5 18,0	89 61 11

Calculations of annual emissions of CO and NO_x from aircraft engine are based on formulas (6.1) and (6.2):

$$M_{CO} = M_{CO\ GO} + M_{CO\ TLO}\ , \text{kg} \tag{6.1}$$

$$M_{NOx} = M_{NOxGO} + M_{NOx\ TLO}\ , \text{kg} \tag{6.2}$$

where, $M_{CO\ GO}$, $M_{NOx\ GO}$ - masses of *CO* and NO_x, which are emitted during ground operations (start, idle running, from landing taxiing – regimes 1, 5); $M_{CO\ TLO}$, $M_{NOx\ TLO}$ - masses of *CO* and NO_x respectively, which are emitted during takeoff and landing operations (takeoff, climb to 1000 m, approach landing from a height of 1000 m – regimes 2, 3, 4).

Calculate masses of CO, which are emitted during ground operations (regimes 1, 5) according to formula (6.3):

$$M_{CO\ GO} = K_{CO} \cdot C_{SP\ LG} \cdot R_{LG} \cdot T_{LG},\ \text{kg} \tag{6.3}$$

where, K_{CO}= 0.0546 – emission index (kg of detrimental compound per kg of fuel) of *CO* during ground operations (table 6.2); $C_{SP\ LG}$ = 0.049 – specific consumption of fuel during regime of low gas, kg/N·hour (table 6.2); R_{LG} – engine thrust at low gas, N; T_{LG} =

15+7 = 22 min =0.37 hour – operating time of engine at low gas for one takeoff and landing cycle (regimes 1,5 at the table 6.1); $R_{LG} = \bar{R} * R_0$, where, $\bar{R}$ – relative thrust (table 6.1), R_0 – maximal thrust of engine, N (table 6.2), R_{LG} =80000*0,07= 5600 N.

Calculation according to formula (6.3):

$$M_{CO\ GO}=0{,}0546*0{,}049*5600*0{,}37=5{,}54\ (kg)$$

Calculate masses of NO_x, which are emitted during ground operations (regimes 1, 5) according to formula (6.4):

$$M_{NOxGO} = K_{NOx} \cdot C_{SP\ LG} \cdot R_{LG} \cdot T_{LG},\ kg \qquad (6.4)$$

where, K_{NOx} =0.0054 – emission index (kg of detrimental compound per kg of fuel) of NO_x relatively during ground operations (table 6.2).

Calculation according to formula (6.4):

$$M_{NOxGO} = 0{,}0054*0{,}049*5600*0{,}37=0{,}55\ (kg)$$

Calculations of CO and NO_x emissions relatively during takeoff and landing operations (regimes 2, 3, 4) are based on formulas (6.5) and (6.6) respectively:

$$M_{CO\ TLO} = W_{CO\ T} *T_T + W_{CO\ C} *T_C + W_{CO\ L} *T_L,\ kg, \qquad (6.5)$$

$$M_{NOx\ TLO} = W_{NOxT} *T_T + W_{NoxC} *T_C + W_{NoxL} *T_L,\ kg, \qquad (6.6)$$

where, $W_{CO\ T}$, $W_{NOx\ T}$ – weight rate of CO and NO_x emissions relatively during aircraft takeoff, kg/hour (table 6.3); $W_{CO\ C}$,$W_{NOx\ C}$ – weight rate of CO and NO_x emissions relatively during climb to 1000 m, kg/hour (table 6.3); $W_{CO\ L}$, $W_{NOx\ L}$ – weight rate of CO and NO_x emissions relatively during approach landing from a height of 1000 m, kg/hour (table 6.3); T_T = 0.7 min=0.012 hour – operating time of engine during takeoff according to table 6.1; T_C =2.2 min=0.037 hour– operating time of engine during climb to 1000 m according to table 6.1; T_L = 4 min=0.067 hour – operating time of engine during descent from 1000 m according to table 6.1.

Calculation according to formula (6.5):

$$M_{CO\ TLO} = 6*0,012+7,5*0,037+18*0,067=1,56\ (kg)$$

Calculation according to formula (6.6):

$$M_{NOx\ TLO} = 89*0,012+61*0,037+11*0,067=4,062\ (kg)$$

Calculation according to formula (6.1):

$$M_{CO} = 5,54 + 1,56= 7,1\ (kg)$$

Calculation according to formula (6.2):

$$M_{NOx} = 0,55 + 4,062= 4,612\ (kg)$$

Calculations of annual emissions of CO and NO_x of aircraft at the zone of airport per year are based on formulas (6.7) and (6.8):

$$M_{CO\ AZ}= M_{CO}\cdot N\cdot n,\ kg/year \qquad (6.7)$$

$$M_{NOx\ AZ}= M_{NOx}\cdot N\cdot n,\ kg/year \qquad (6.8)$$

where, N – annual quantity of takeoff-landing of the aircraft at the airport; n – quantity of engines of the aircraft.

Calculation according to formula (6.7):

$$M_{CO\ AZ}=7,1*100*2=1420\ (kg)$$

Calculation according to formula (6.8):

$$M_{NOx\ AZ} =4,612*100*2=922,4\ (kg)$$

6.2 Calculation of the emissions parameters M/R_0, g/kN for CO and NO_x from one aircraft engine

Calculate emission parameter M_{co}/R_0 for CO from one aircraft engine according to following formula:

$$\frac{M_{CO}}{R_0} = \frac{7100}{80} = 88{,}75 \ (\frac{g}{kN})$$

Calculate emission parameter M_{NOx}/R_0 for NO_x from one aircraft engine according to following formula:

$$\frac{M_{NO_x}}{R_0} = \frac{4612}{80} = 57{,}65 \ (\frac{g}{kN})$$

ICAO standards according to control emission parameters for modern engines are the following:

M_{CO}/R_0 = 118 g/kN, M_{NOx}/R_0 = (40...80) g/kN

After calculations we have next values M_{CO}/R_0 =88,75 g/kN, which is possible value according to standards of control emission parameters, and M_{NOx}/R_0 =57,65 g/kN, which is normal value according to standards of control emission parameters.

For decreasing value of emissions we can make some measures. There are several ways to decrease emissions of engine. One of the effective methods of regulation of emissions mass is optimal choice of dwelling time of fuel in combustion zone, that allows to rationally balance CO, C_xH_y and NO_x. Second way to decrease emissions mass is to turn off the some engines during landing taxiing after landing of aircraft, and working engines will develop higher thrust, meanwhile summary consumption of fuel and emissions of CO and NO_x will become lower.

Conclusion to the part 6

According to calculations engine emissions during regimes of start, idle running before takeoff (regime of low gas), from landing taxiing (regime of low gas) are $M_{CO\ GO}$= 5,54 kg, $M_{NOx\ GO}$=0,55 kg, and during regimes of takeoff, climb and approach landing from a height of 1000 m are $M_{CO\ TLO}$=1,56 kg, $M_{NOx\ TLO}$=4,062 kg. We can conclude that the maximum emission of NO_X occurs on the take-off mode of the engine and modes close to it (when taking off and taking off the altitude of the aircraft) and the maximum emission of CO occurs on the idle and taxiing modes of the engine. The most long and environmentally harmful is the low gas mode (relative thrust is 3 ... 9% of its maximum value). Such small values of the relative thrust of the engine occur during taxiing before takeoff and after landing, as well as during engine warm-up after start-up, occurring in the airport area (airport area means space limited by 1000 m altitude and aerodrome size). Annual emissions of CO and NO_x of aircraft at the zone of airport per year are $M_{CO\ AZ}$=1420 kg, $M_{NOx\ AZ}$ =922,4 kg. By using measures for decreasing emissions, which are given above, we can decrease level of emissions.

GENERAL CONCLUSION

This work was aimed on the solution of the problems and approaches of cargo airdrop. It was considered ways for cargo transportation and main factors affecting on the choice of type of cargo delivery. As usually military actions take place in hard-to-reach regions and time of cargo delivery is limited, it was chosen way of transportation by air. Also it was analyzed types, methods, systems of cargo airdrop. After analyzing different systems characteristics and performances, it was chosen Container Delivery System as way of cargo drop, due to it simplicity, cheap cost, effectiveness in use. As method of cargo drop was chosen gravity method, due to the fact, that it is the most suitable for given system. Than it was analyzed main elements of this system and identified that in accordance with NATO standards airborne transport equipment should include buffer stop for realization airdrop of cargo by gravity method. It was also revealed that modern Ukrainian aircrafts do not have this installation as part of air transport equipment and it was decided to develop new buffer stop.

It was investigated actual buffer stops installed on C-130, C-17, A-400M aircrafts and detected their construction advantages and disadvantages for following development of new installation for integration it on military aircrafts.

It was performed preliminary design procedure of aircraft for development of the research object. In this part of diploma work were selected primary parameters for designed aircraft by analyzing prototypes An-178, An-74, KC-390 characteristics. It was carried out calculations of the main parts of an aircraft, such as span of the wing – 30,32 m, area of the wing – 98,58 m, length of the fuselage is 29,95 m, base of landing gear is 11,37 m and track is 4,37 m. We have also checked the mass position of the main parts of the aircraft and main equipment and furnishing by its distance from the main aerodynamic chord. The wing MAC leading edge position relative to fuselage is equal to 12,061 m, which corresponds to desired values of the designing aircraft. Also in this part it was carried out determination of the center mass position characteristics. Airplane center of gravity position variants are equal from 12,61 m to 12,80 m these values correspond to desire for that type of aircraft.

It was studied containers characteristics, their purpose and construction. Container of type A-22 was chosen as element for container delivery system, which has next characteristics: width and length is 1219,2 mm, height is 25,4 mm, load weights are from 501 to 2200 lbs. Also it was calculated center of gravity of one load installed on container with full airborne equipment used during process of cargo airdrop by using gravity method. Center of gravity of container for the first calculation case is in the range from 583,7 mm to 877 mm; for the second calculation case is in the range from 685,5 mm to 976,7 mm. It is necessary to obtain these values for correct layout of containers on board of aircraft due to the fact that during process of cargo airdrop centers of gravity of aircraft changes for preventing emergency situations it is necessary to locate cargo in boundaries of «centering house» of aircraft.

Then it was determined main structural features of buffer stop:

- the basis which will be executed on the principle of the military pallet 88x108 MIL-P-27443E (USAF);
- a persistent wall which will accept loading from A-22 containers;
- struts between the abutment wall and the base;
- mooring straps (from the set of mooring equipment) between the abutment wall and mooring sockets on the floor of the aircraft.

Calculation of the stress-strain state of the nodes of the strut of buffer stop was performed by using the module "NX Advanced Simulation". After obtained calculated values of equivalent stresses acting on installation of the strut of buffer stop and it safety factor coefficient it can be concluded that the static strength of the designed structural elements is sufficient.

Main advantages of developed buffer stop are the following:

1. Size of construction: 1200×1219,2×800 mm. By minimizing sizes of construction, strength characteristics of it doesn`t decrease. Developed installation can withstand load of 22591 kg but it the same time it much less in sizes than actual developed buffer stops.

2. Time of assembly and disassembly. For install buffer stop installation in work position it is necessary only to install struts.

3. Have large contact with load. All area of persistent wall of buffer stop contact with load.

4. All constructional elements are interchangeable, so that the installation is cheap and easy to manufacture and it components can be easily found.

5. Buffer stop can be fixed in any position on roller equipment.

6. It isn`t necessary to use special tool for it assembly, as it used standard fasteners between structural elements.

Buffer stop facilitates the work of a person in the process of loading cargo on board and also to prevent abnormal emergencies during the flight and at the process of dropping cargo from the aircraft. The results of the work can be implemented in aviation airborne industry by the adaptation for empowering of airborne transport equipment.

REFERENCES

1. Parachute equipment "Universal". Equipment and weapons: website. URL: https://military.wikireading.ru/54717 (date of the application: 8.09.2020).

2. The aerial delivery of humanitarian aid in Syria: options and constraints. The Washington institute: website. URL: https://www.washingtoninstitute.org/policy-analysis/view/the-aerial-delivery-of-humanitarian-aid-in-syria-options-and-constraints (date of the application: 8.09.2020).

3. Army Technical Publication № 4-48: as of 21.12.2016 y./ Headquarters. Department of the Army. Washington: Aerial Delivery, 2016, 94 p.

4. Container Delivery System. GlobalSecurity.org: website. URL: https://www.globalsecurity.org/military/systems/aircraft/systems/cds.htm (date of the application: 18.09.2020).

5. Airborne cargo for coalition forces. InMilitary: website. URL: https://invoen.ru/analitika/desantirovanie-grusov-koalizii-tshast1/ (date of the application: 20.09.2020).

6. Chupriyan A.P. Modern aspects of humanitarian operations in emergency situations and armed conflicts. Modern aspects of humanitarian operations in emergency situations and in armed conflicts: collection of materials of participants of the 14th international scientific-practical conference on the problems of protecting the population and territories from emergency situations: Moscow, Russia, May 20, 2009, 320 p.

7. Ways to improve the system of landing support of military units and units of highly mobile landing troops/ V. Dyachenko and others. Ukraine, 2014, 141p.

8. FM 63-2-1. Division Support Command Light, Airborne and Air Assault Divisions. GlobalSecurity.org: website. URL: https://www.globalsecurity.org/military/library/policy/army/fm/63-2-1/index.html (date of the application: 30.09.2020).

9. The paratroopers are testing American parachutes and controlled cargo airdrop systems. Ministry of Defence Ukraine: website. URL:

https://www.mil.gov.ua/news/2020/06/16/desantniki-testuyut-amerikanski-parashuti-ta-kerovani-sistemi-desantuvannya-vantazhiv/ (date of the application: 5.10.2020).

10. Buffer stop assembly: patent 6,568,636 B2 United States: appl. № 09/778, 640; publication US 2002/0104925 A1, August 8 2002 y.

11. Cargo restraining assembly, cargo loading system and aircraft: patent 9,975,636 B2 United States: appl. № 14/619,819; publication US 2015/0225083 A1, August 13, 2015 y.

12. Buffer Stop Assembly. Capewell Aerial System LLC: website. URL: https://capewellaerialsystems.com/product/buffer-stop-assembly-bsa/ (date of the application: 8.10.2020).

13. Buffer Stop Assembly Stock Photos and Images. Alamy: website. URL: https://www.alamy.com/stock-photo/buffer-stop-assembly.html (date of the application: 15.10.2020).

14. D. Kushpil. Report on the strategic environmental assessment of the draft Aviation Transport Strategy of Ukraine for the period up to 2030. Ukraine: 2019 y. 28 p.

15. Aerial Delivery System. A-22 and A-7A cargo container system. CIMSA: website. URL: http://www.cimsa.com/pdf/parachute/A22%20&%20A-7A_ENG.pdf (date of the application: 20.10.2020).

16. Container delivery system. Unguided parachutes. MMIST: website. URL: https://www.mmist.ca/unguided-parachutes.html (date of the application: 20.10.2020).

17. G-12 Cargo Parachute Assembly. MILLS manufacturing: website. URL: https://www.millsmanufacturing.com/products/g-12-parachute/ (date of the application: 25.10.2020).

APPENDIX A

INITIAL DATA