MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

Department of aircraft design

APPROVED BY
Head of department
D.Sc., professor
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«___ »___________2020.

DIPLOMA WORK
(EXPLANATORY NOTE)
OF EDUCATIONAL DEGREE
«MASTER»

ACCORDING TO THE EDUCATIONAL PROFESSIONAL PROGRAM
«AIRCRAFT EQUIPMENT»

Theme: «Modular ramp for aircraft loading»

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Labor protection: **Ph.D., associate professor**	__________	**O.V. Konovalova**
Environmental protection: **Ph.D., associate professor**	__________	**L.I. Pavliukh**
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Kyiv 2020

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

VLADYSLAV HERASIMOV

1. Topic **«**Modular ramp for aircraft loading**»**, approved by the Rector's order № 1906/ст of October 5, 2020.

2. Thesis terms: from October 5, 2020 to December 13, 2020.

3. Initial data: V_{cr}=750 km/h, flight range L=2000 km, operating altitude H_{op}=8 km, crew members 2, payload 40 tons.

4. Content: analysis of modern problems of ramps for loading aircraft, methods and procedures of developing a modular ramp, preliminary design of aircraft as an object for the implementation of research and design results, development of elements of modular ramp for loading aircraft, analysis of harmful and dangerous production factors, calculations of carbon monoxide and nitrogen oxide emissions by aircraft.

5. Required material: general view of the aircraft (A1 × 1), layout of the aircraft and modular ramp (A1 × 1), drawing of the modular ramp assembly (A1 × 1) , drawing of the modular ramp parts (A1 × 1). Graphic materials are made in CATIA V5, ANSYS Workbench, AutoCAD.

6. Thesis schedule

№	Task	Time limits	Done
1	Obtaining the task, processing statistical data	5.10.2020 – 12.10.2020	
2	Methods and procedures of developing a modular ramp	13.10.2020 – 14.10.2020	
3	Aircraft layout and determining the alignment of the aircraft	15.10.2020 – 23.10.2020	
4	Graphic design of the aircraft layout	24.10.2020 – 1.11.2020	
5	Graphic design of a modular ramp	2.11.2020 – 16.11.2020	
6	Calculation of ramp strength	17.11.2020 – 26.11.2020	
7	Ramp design optimization	27.11.2020 – 29.11.2020	
8	Completion of the explanatory note	30.11.2020 – 5.12.2020	

7. Special chapter consultants

Chapter	Consultants	Date, 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: «___» ___________ 2020.

Supervisor of diploma work ______________ M.V. Karuskevich

Task for execution is given for ______________ V.O. Herasimov

ABSTRACT

Master degree thesis “Modular ramp for aircraft loading”

82 pages, 20 figures, 11 tables, 12 references

Object of study – The process of the module ramp design on the base of the current designs analysis, proposed new concept and Finite Elements Analysis.

Subject of study – The loading equipment of the cargo aircraft

Aim of master thesis – New modular ramp for aircraft loading

Research and development methods – method of multiple comparison, new concept proposal, computer-aided design, Finite Elements Analysis.

Novelty of the results – The results are based on the analysis of current demands, have obtained with advanced methods of design and meet requirements of the industry.

Practical value - The result of the work can be implemented in the Aviation transport industry by the adaptation for wide spectrum of cargo aircraft and different nonstandard loads.

AIRCRAFT, PRELIMINARY DESIGN, CARGO RAMP, STRENTH, MODULAR CARGO RAMP, STRENTH CALCULATION, FINITE ELEMENTS ANALYSIS

CONTENT

ABBREVIATIONS

ICAO – International Civil Aviation Organization;
EASA – European Union Aviation Safety Agency;
AC – Aircraft;
FADEC – Full Authority Digital Engine Control;
FEF – Fully Equipped Fuselage;
FEW – Fully Equipped Wing;
CG – Center of gravity;
MAC – Mean aerodynamic chord;
CM – Center of mass;
FEM – Finite Element Method;
FEA – Finite Element Analysis;
SF – Safety Factor;
VDT – Visual Display Terminals;
PC – Personal Computer.

INTRODUCTION

Cargo planes are designed to carry different kinds of loads with wide variety of their dimensions. Good examples of nonstandard loads are automobiles, trucks with trailers, helicopters, boats on trailers carried recently by the Antonov Transport Company.

To extend the range of loads carried by the cargo planes the new designs of ramp are demanded.

The aim of the diploma paper is a design of new modular cargo ramp for aircraft loading and unloading.

To gain this aim the following objectives have been formulated:

- to analyze current trends in the cargo planes design and cargo equipment;
- to investigate actual loading and unloading aircraft cargo ramps and detection of main disadvantages of them;
- to propose improved design of cargo ramp due to leveling of shortcoming of investigated cargo ramp;
- to determine methods of aim achievement – creation of 3D models and stress-strain analysis;
- to engage preliminary design procedure for development of the object for the module cargo ramp for aircraft loading application;
- to select primary parameters for designed aircraft;
- to estimate geometrical parameters of the wing, tail unit, fuselage, landing gear, etc.;
- to select engines taking into account required take off power;
- to estimate range of center of gravity locations.

The designed modular cargo ramp for aircraft loading provides loading of up to 20000 kg weight.

As an example of the aircraft for the implementation of the new ramp the 2000 km range with maximum payload, 750 km/h cruising speed, 163466 kg of takeoff mass 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, etc.

The diploma work incudes also labor protection and environmental protection parts.

The part “Labor protection” considers the problem of design engineers that work with computers and near manufacturing shops.

In the part “Environmental protection” some aspects of the influence of aircraft on environment and emissions calculation are described.

The work follows Guide for Master’s Diploma works, meets requirements of the Native and International Airworthiness standards.

1 THE PROBLEM OF LOADING VEHICLES IN AIRCRAFT AND OVERPASS FOR HEAVY CARGO AIRCRAFT

1.1 Description of the problem

During loading and unloading of a cargo aircraft some characteristics of the vehicle may cause problems associated with ramp entry angle at ramp crest. As the result vehicle can be damaged or crashed at critical points (Figure 1.1 – 1.3). There are vehicle characteristics that can be subjected to this problems:

- Vehicle with low ground clearance (Figure 1.1, 1.2);

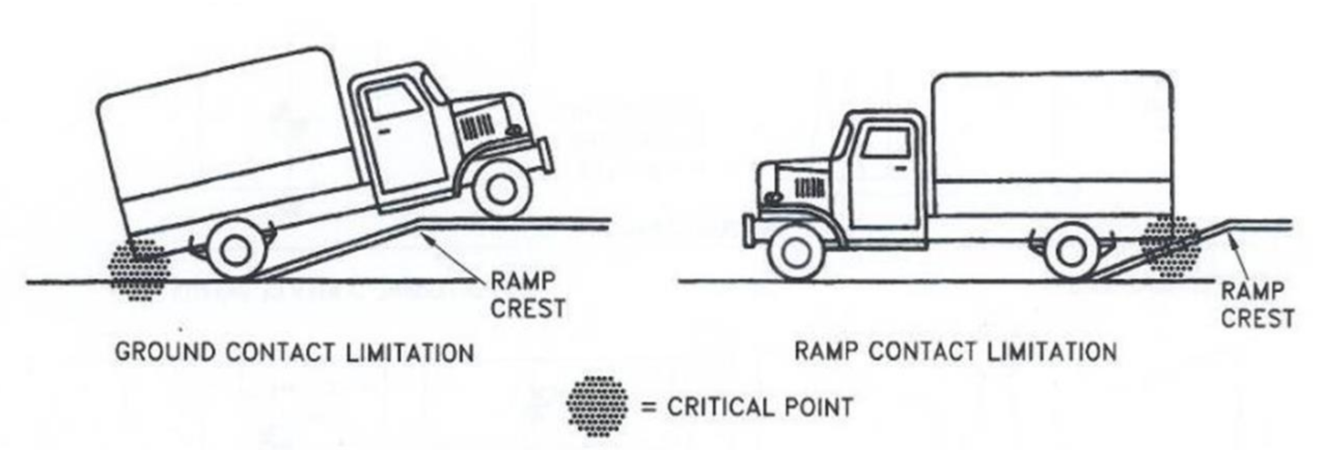

Figure 1.1 – Vehicle with low ground clearance and long overhang

- Vehicle with long wheel base (Fie 1.2);

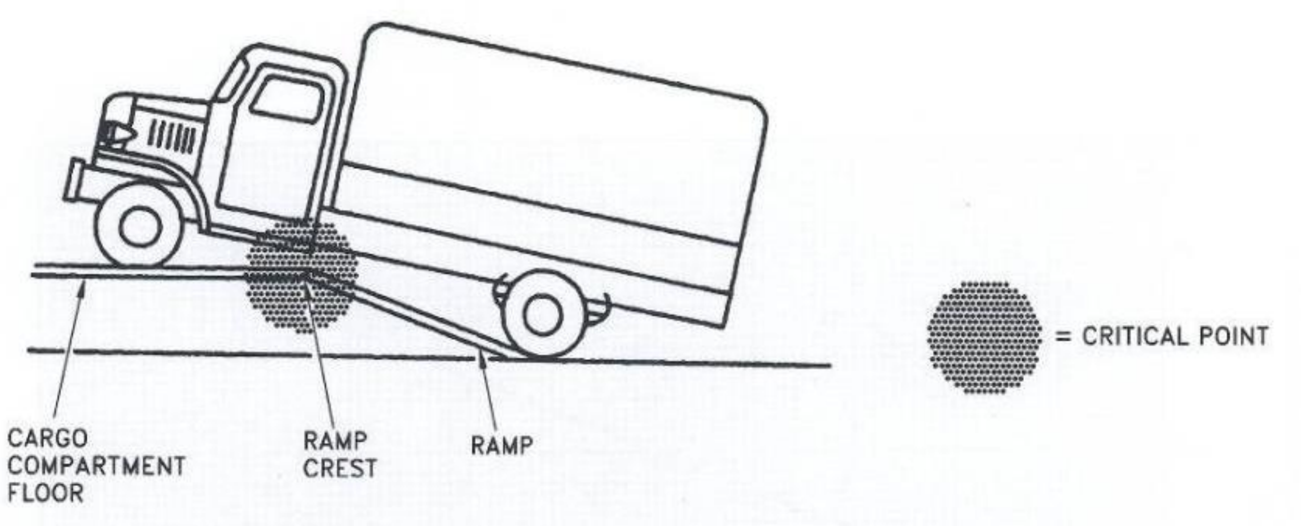

Figure 1.2 – Vehicle with long wheel base and low ground clearance

- Vehicle with long overhang (Figure 1.1, 1.3);
- Tall vehicle with long overhang (Figure 1.3).

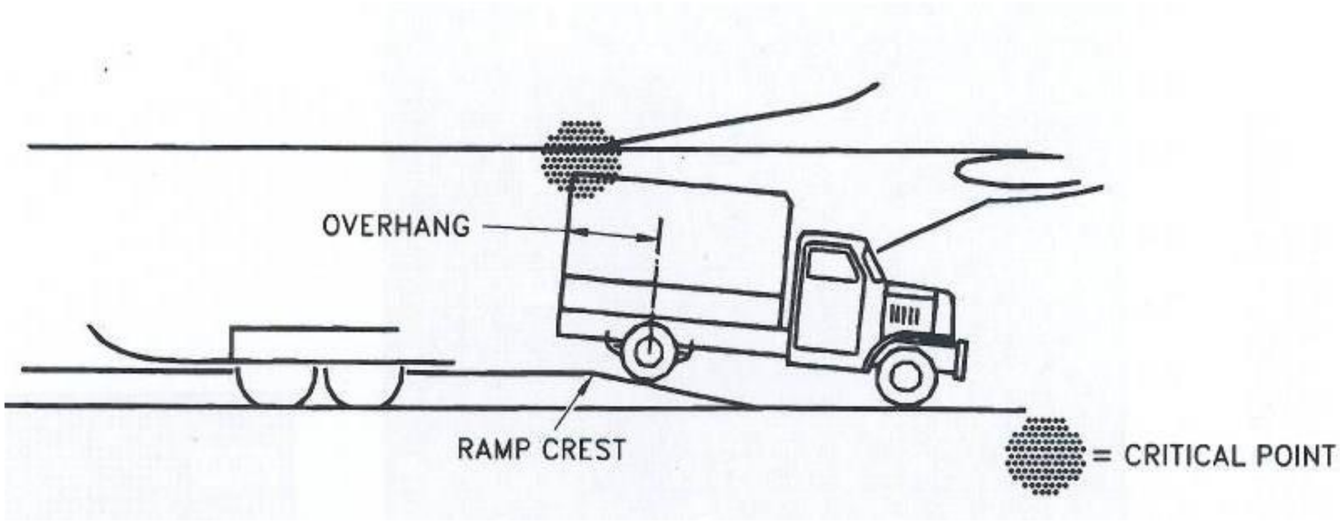

Figure 1.3 – Tall vehicle with long overhang

In the past such design features were solved with help of lumbers and plywood. Construction from this units consist of many layers and its set-up and break-down time could run into many hours and even days. Once the cargo is loaded into the freighter the wooden equipment then has to be loaded into the aircraft and it is understandable that number of lumbers was far from satisfactory when it comes to usability and efficiency performance. Required number of lumbers means high mass and intake space in addition to cargo. And even if occupied space will be neglected, the weight of the lumbers alone negatively effect on flight performances which in turn leads to decreased flight range, increased thrust on different regimes of flight so higher noise pollution and fuel consumption. And a result of this increased cost of aircraft operations.

Growing air freight market forced to reduce negative effects of lumber and plywood approach shoring. So collapsible modular ramps were founded. This is the equipment that has metal units in its construction which are lighter and stack into a smaller space on aircraft in comparison with wood in strength and size ratio, and has adequate number of parts that saves time by quicker setup performance. Also metal instead of wood leads to such positive moments like saving the trees which is actual nowadays and because of longer lifespan of metal in comparison with wood it saves money. One of the weightiest characteristic is unlimited configurations thanks to modularity of the construction. There are not so many ramps for such purposes and one of these few devices is described in the next subsection.

1.2 Overpass for heavy cargo aircraft loading

There are exist several ramps for loading and unloading aircrafts. The most advanced is overpass for loading and unloading mono-cargo and wheeled vehicles into aircraft such as a heavy transport aircraft AN-124. This equipment has few advantages in comparison with its analogies and it is more advanced in design. But also there are several very specific features that lead to disadvantages in using for broader purposes.

An overpass for loading and unloading mono-cargo and wheeled vehicles into aircraft of the type of heavy transport aircraft AN-124, containing the body of overpass 1 (Figure 1.4, 1.5), having vertical supports, loading platform 2 (Figure 1.4, 1.5) which is equipped with guides 3 (Figure 1.4 - 1.6) and is made with the ability to move in a vertical plane, while the overpass body is made of several typical sections 4 (Figure 1.4 - 1.6), installed in two parallel rows and docked with each other in rows using docking nodes (Figure 1.6).

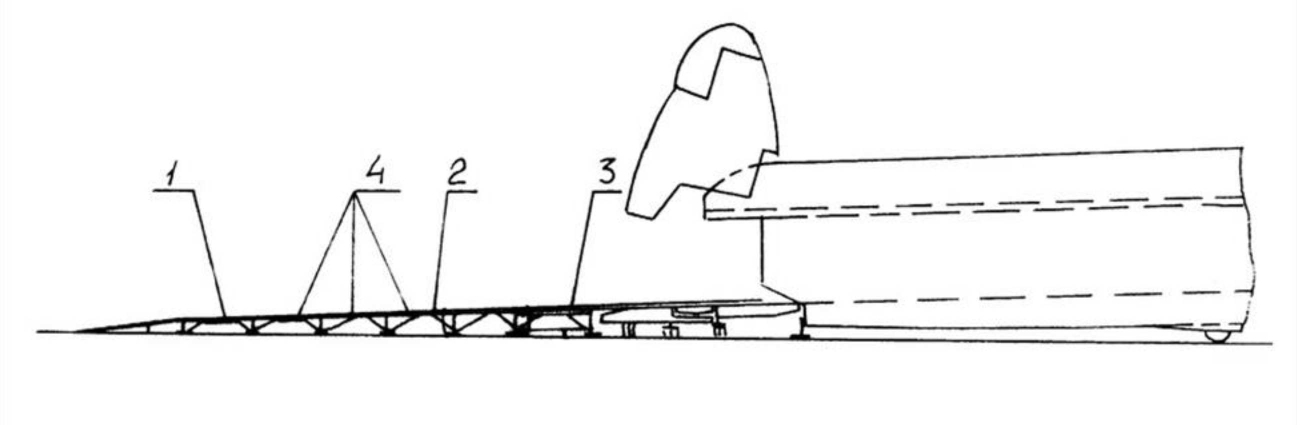

Figure 1.4 – Side view of overpass installation

Each section of the overpass body is made of a frame structure and contains an upper load-bearing belt fixed on racks with struts, forming the mentioned loading area, a lower load-bearing belt equipped with box-shaped transverse beams 5 (Figure 1.6), connected to each other longitudinal beams, and height-adjustable screw supports 6 (Figure 1.6), including supports and plates and made at least two for each second sections.

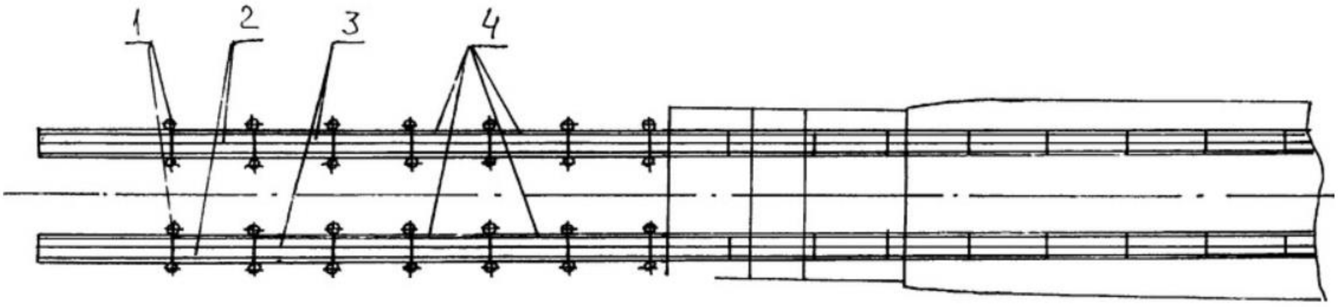

Figure 1.5 – View from above of overpass installation

The overpass is made collapsible with the ability to change the distance between the rows of sections depending on the track of wheeled vehicles and with the ability to change its length and height by changing the number and height of typical sections, while the said guides are made in the form of an W-shaped profile, with the possibility of installing into its grooves of roller devices for moving the load, characterized in that said upper load-bearing belt is made of said guides provided with support plates attached from below, and said lower load-bearing belt is made only on the front section, and said vertical supports are made two on the front section and one on the front side on all subsequent sections and contain the mentioned racks, hinged to the transverse beam, made one for each section, except for the front one, which has two transverse beams, containing the mentioned height-adjustable screw supports, while the guides of the W-shaped profile fixed n on the racks and struts of the overpass by means of bolts inserted into the holes of the docking units of the upper part of the racks and into the holes of the fork brackets mounted in pairs along the edges on the lower surface of the W-shaped profile of the guides, and the racks and struts are fixed by means of bolts inserted into the holes of the docking units of the lower part racks and into the holes of the docking units of the inclined struts with brackets mounted on the upper surface of the transverse load-bearing beams of the previous sections, and the loading platform is configured to install and fasten the end of the W-shaped profile of the guides free from fasteners on the supports flyover characterized in that the overpass body is made with the possibility of folding the overpass sections for storage and transportation in an aircraft.

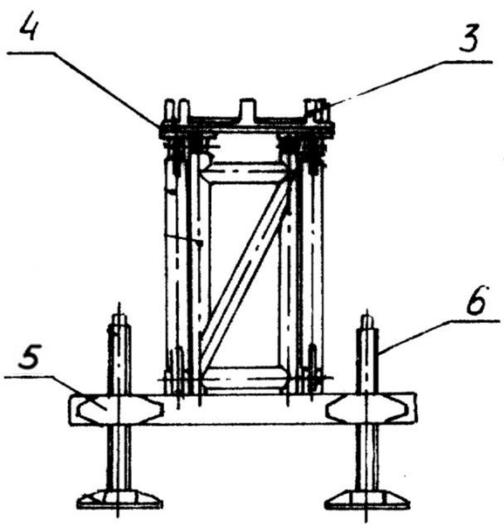

Figure 1.6 – Overpass support

The invention relates to aviation technology, to devices for loading and unloading mono-cargoes and wheeled vehicles from a heavy transport aircraft AN-124 and can also be used in shipbuilding, mechanical engineering and other fields of technology when loading and unloading mono-cargoes with a running load on the base of 10 t/m and wheeled vehicles [1].

So according to this description of overpass construction it can be noted that the main design features of it directed on specific using for one type of heavy cargo aircraft. Compeering with same directed equipment this specific ramp has advantages in weight and relative simplicity of setting up. But talking about broader applicability

But speaking of a wider application, this ramp has a number of disadvantages that do not depend on it. The main reason for all problems is the narrow focus and hence the complexity of the design.

The complexity of the structure leads to the fact that the weight of the structure is increased, its dimensions due to the complexity are greater than it could be, the complexity of the mechanisms entails an increased time for assembly, installation and adjustment. The same problem of overweight for flight performance and fuel consumption is also rising. And as it was written earlier, the level of emissions rises and the cost of operating such equipment increases due to the combusted fuel.

If talking about the production of such equipment, the complexity of the design also entails many negative aspects. Firstly, it is the complexity and low speed of production of many parts, such as, for example, screw supports. They have threads that are relatively expensive to manufacture. Consequently, the price of such a ramp is quite high for the end user. Secondly, the requirement for personnel should be high in such a production of relatively complex parts. The complexity of the design also entails the presence of a defects during manufacturing, which also costs the manufacturer money.

When used with cargo aircraft of different sizes, the question of excess technical characteristics and the presence of W-shaped guides will immediately arise. Smaller cargo aircraft such as the AN-178 or AN-132 and their foreign counterparts are more popular. There is also the AN-70 and its European analogue A400M. For such aircraft, the need for W-shaped guides immediately disappears due to the different design of the floor of their cargo cabins. A running load of 10 t/m is not so necessary for cargo, which is transported in most cases by cargo aircraft.

So as a result, there are a number of disadvantages that do not allow the use of the overpass for loading and unloading single-cargo and wheeled vehicles into aircraft such as the AN-124 heavy transport aircraft with a large number of cargo aircraft.

1.3 Requirements for the modular cargo ramp for aircraft loading

The modular aircraft loading ramp, which will be able to be used with a wide variety of aircraft, should negate the disadvantages described in the previous section. The design of such equipment should be as simple as possible, both in use and in production.

The ramp must be applicable over a wide range of heights, that is, it must be adjustable. Ease of use is realized with the minimum required installation parts and materials. The most suitable material for this construction is aluminum alloy. It perfectly combines the ratio of price and required characteristics. Ease of use means that operating personnel must spend a minimum amount of time and effort to work with this ramp. The elements must have a minimum weight and be easy to install. To be interchangeable in case any structural element fails.

The ramp elements should be of simple shape. In their production, sheet materials, profiles of simple sections, for example, a U-shaped profile or a square-section profile, must be involved. Such a construction can be simply welded.

The ramp supports should only consist of two parts, one of which will be adjustable, and two steel pins to fix these parts together. This simple design allows quick adjustment of the ramp working height. Also, supports should be 3-4 different types with a difference between them in adjustable height. The fixation of the elements of the modular ramp between the supports should also be carried out with steel pins.

The required strength of such a modular ramp must withstand the load of various types of wheeled vehicles, such as SUVs, RVs, trucks, helicopters, etc.

The methods and ways to reach described characteristics for the modular ramp for aircraft loading will be described in the next paragraph.

Conclusion to the part 1

The problem of loading vehicles in aircraft and ways to overcome has been introduced. Design and construction of one of the advanced cargo ramps for loading and unloading heavy cargo aircraft were described. Advantages and disadvantages of it were determined. Requirements for modular cargo ramp were determined, main of them are simple design, low weight, low in cost and easy to operate and manufacture.

As a result of the analysis presented in part 1 the aim and objectives of the work have been formulated.

The aim of the diploma paper is a design of modular cargo ramp for aircraft loading and unloading.

To gain this aim the following objectives have been formulated:

- to analyze current trends in the cargo planes design and cargo equipment;
- to investigate actual loading and unloading aircraft cargo ramps and detection of main disadvantages of them;
- to propose improved design of cargo ramp due to leveling of shortcoming of investigated cargo ramp;
- to determine methods of aim achievement – creation of 3D models and stress-strain analysis;
- to engage preliminary design procedure for development of the object for the module cargo ramp for aircraft loading application;
- to select primary parameters for designed aircraft;
- to estimate geometrical parameters of the wing, tail unit, fuselage, landing gear, etc.;
- to select engines taking into account required take off power;
- to estimate range of center of gravity locations.

2 METHODS AND PROCEDURES

To solve the primary aim of the diploma paper and objectives described in previous section the following methods and procedures have been selected.

2.1 Method of 3D modeling

After determination of main required characteristics of the modular ramp it is required to create a concept of how it will look with applied engineering solutions. For such purpose building of realistic 3D models can be applied. Method of 3D modeling gives possibility to create required parts and connect them in assemblies in real time. Working with realistic models and assemblies much more convenient than with drawing. And the main ultimate feature of creation of 3D models is possibility to use special software to make a finite element method (FEM) analysis for stress-strain characteristics. But more details about FEM analysis using software are in next subtitle.

Software CATIA V5 is the great tool for creation of engineering 3D models. CATIA is the World's Leading Solution for Product Design and Experience. It is used by leading organizations in multiple industries to develop the products we see and use in our everyday lives [2]. First result of 3D model creation is parts (Figure 2.1).

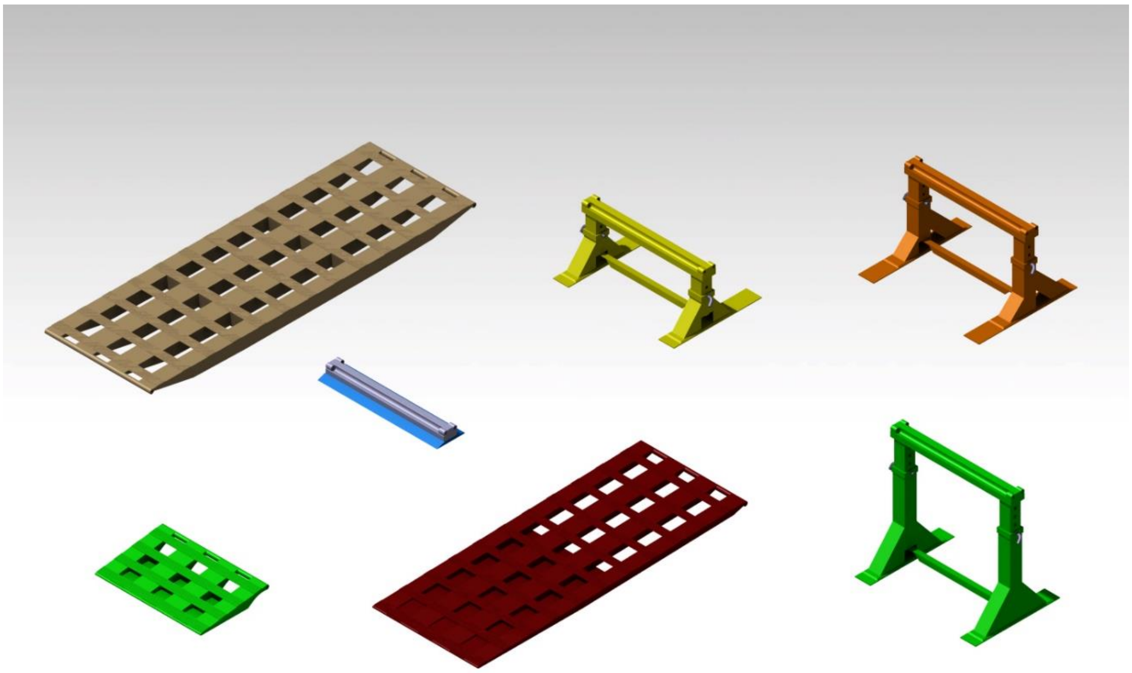

Figure 2.1 – Parts for modular ramp created in CATIA V5

After parts are created them can be gathered into the assemblies (Figure 2.2). Assemblies give general picture of created equipment and let to correct some identified deficiencies. So finally the most applicable geometry and connections methods are developed.

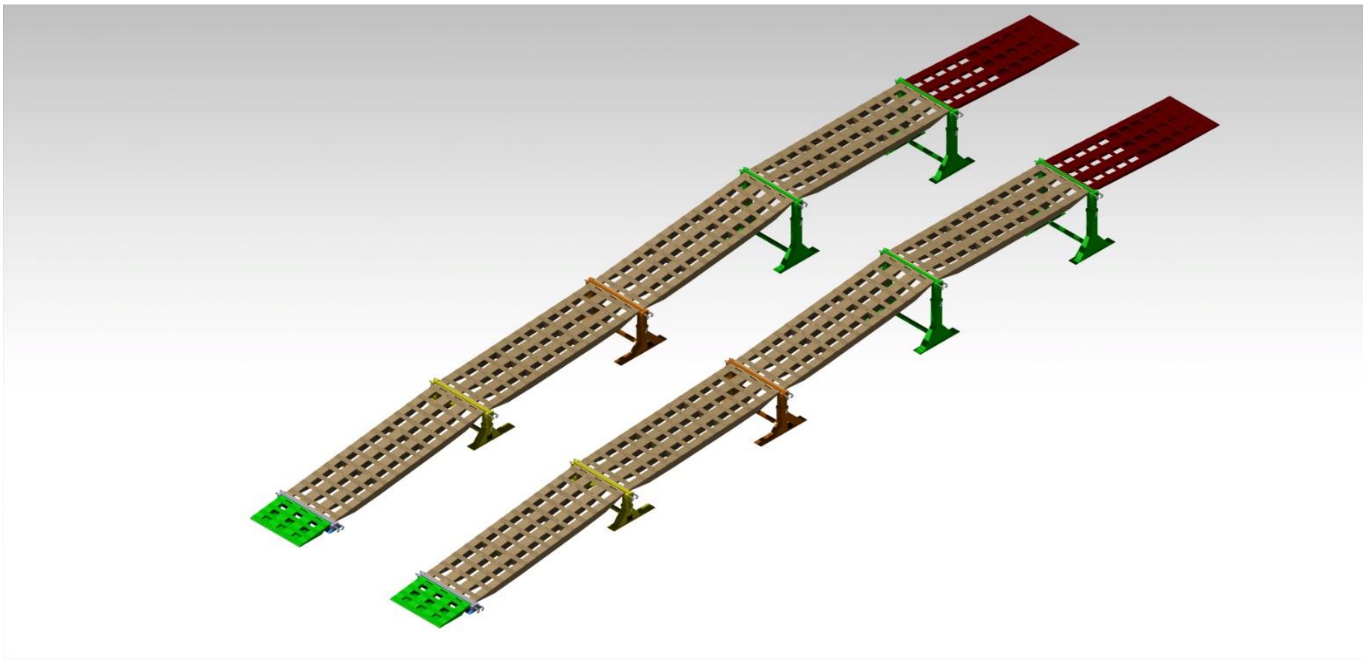

Figure 2.2 – Modular ramp assembly

Prepared assemblies with defined geometrical parameters, wall thickness, and range of regulations are ready for stress-strain analysis. CATIA V5 is advanced engineering software and has inbuilt Analysis and Simulation application that can be used for FEM analysis of created ramp. But there is better specialized software for this purpose. It is called ANSYS Workbench and it will be used for FEM stress-strain analysis of modular ramp for loading aircraft.

2.2 FEM stress-strain analysis

ANSYS structural analysis software enables you to solve complex structural engineering problems and make better, faster design decisions. With the finite element analysis (FEA) solvers available in the suite, you can customize and automate solutions for your structural mechanics problems and parameterize them to analyze multiple design scenarios. You can also connect easily to other physics analysis tools for even greater fidelity. ANSYS structural analysis software is used across industries to help engineers optimize their product designs and reduce the costs of physical testing [3].

So ANSYS has all opportunities to give required results of testing and its main theme is advanced FEM of analysis and meshing creation.

The finite element method is a systematic procedure of approximating continuous functions as discrete models. This discretization involves finite number of points and subdomains in the problem's domain. The values of the given function are held at the points, so-called nodes. The non-overlapping subdomains, so-called finite elements, are connected together at nodes on their boundaries and hold piecewise and local approximations of the function, which are uniquely defined in terms of values held at their nodes. The collection of discretized elements and nodes is called the mesh and the process of its construction is called meshing [4] (Figure 2.3).

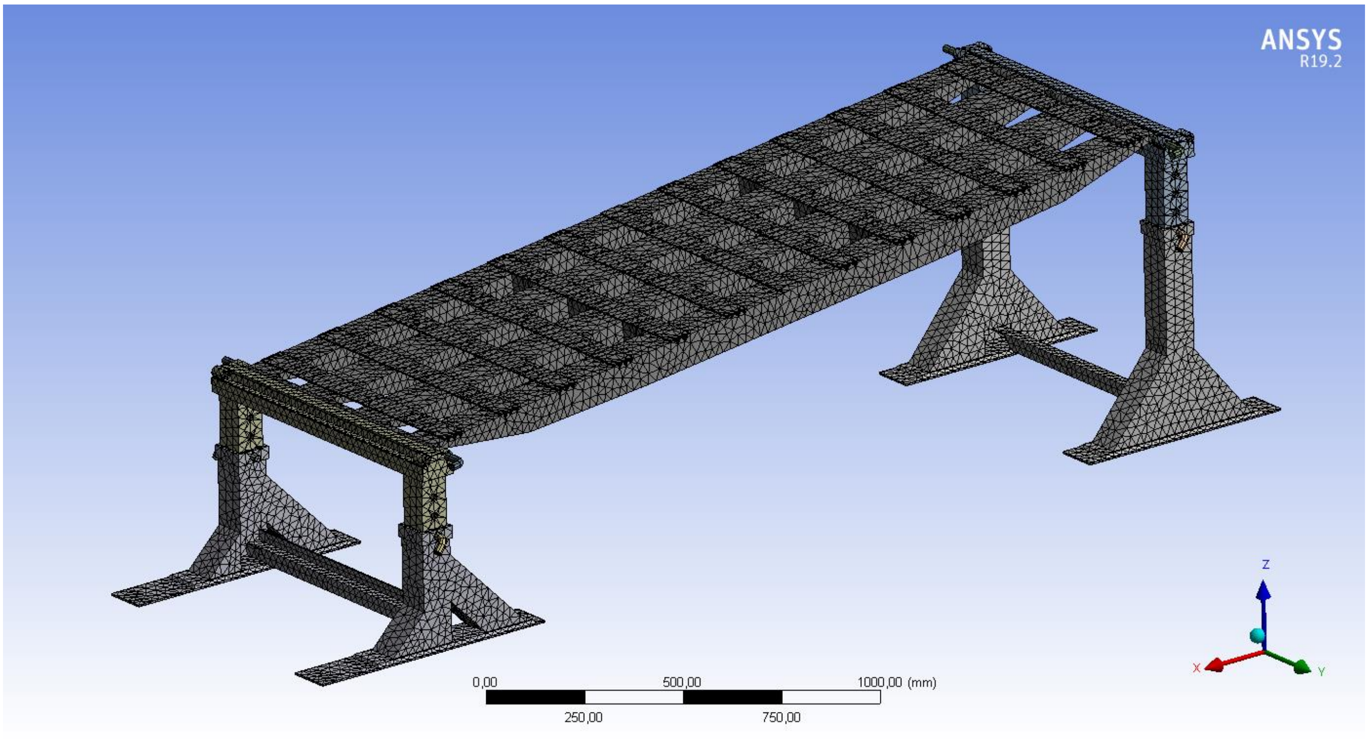

Figure 2.3 – Meshing in ANSYS static structural application

Results of structural analysis are stress parameters (Figure 2.4) and deformation range (Figure 2.5). These data gives possibility to see where improving of construction required or where excess of construction characteristics takes place which in its turn gives possibility to improve weight and geometry characteristics or in other words – to optimize construction.

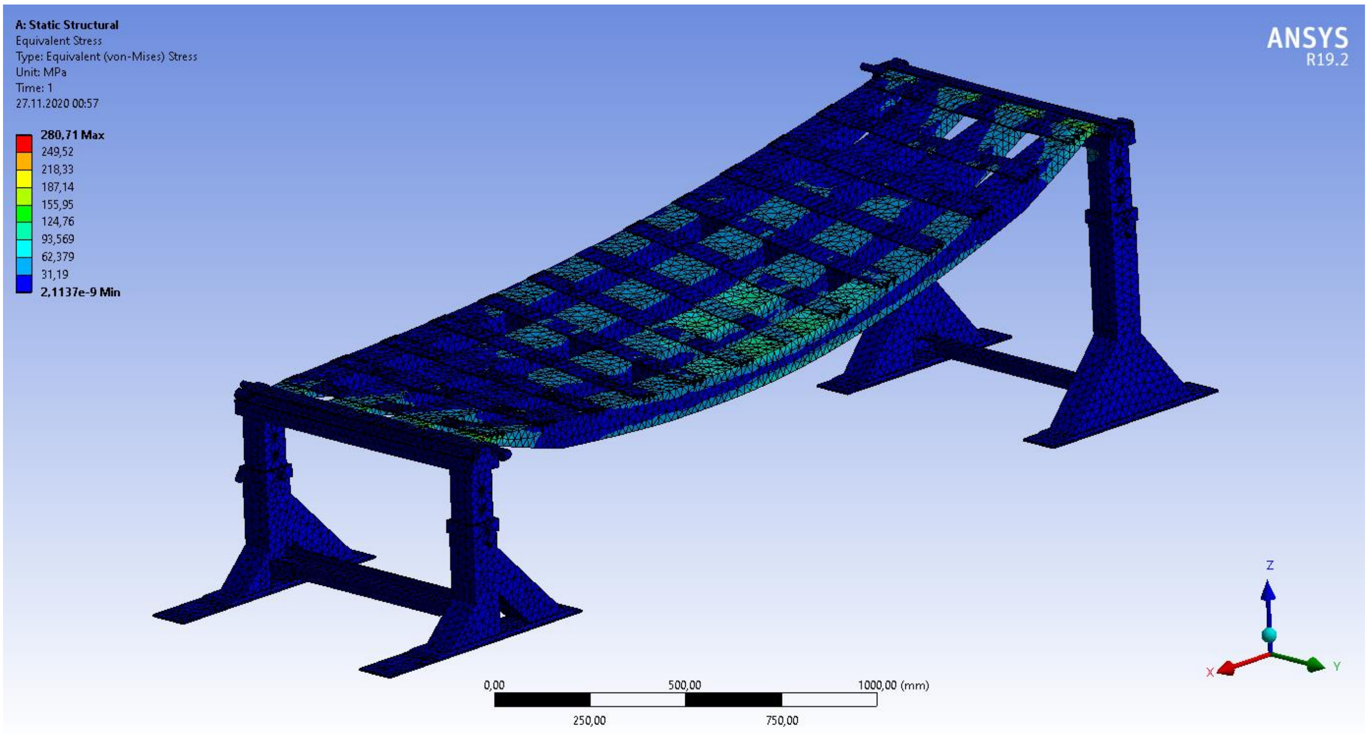

Figure 2.4 – Von-Mises Stress visualization in ANSYS

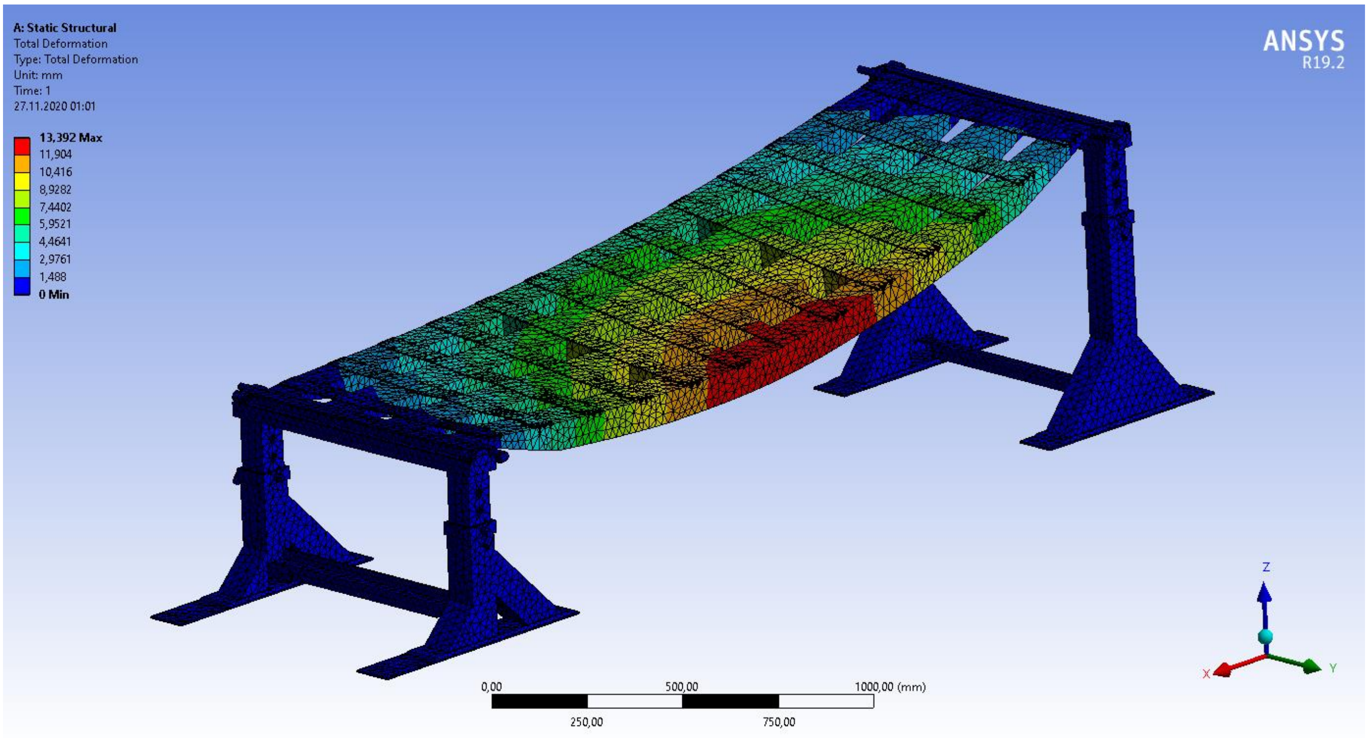

Figure 2.5 – Total deformation visualization in ANSYS

After getting required information about weak spots of the construction of modular ramp from FEM analysis in ANSYS it is required to back into CATIA and make required improvements, check results after that in ANSYS again and as a result, get the required design of modular ramp for loading aircraft.

2.3 Preliminary design procedure for development the object for module ramp application

The object for module ramp application should be taken with the expectation that it will be a common aircraft type average in its characteristics, which will show most of the shortcomings and flaws.

The selecting of the optimal design parameters of the aircraft is based on the analysis of airplanes of close or same category. Then parameters required for creation of general view and layout of aircraft should be determined. Approximate algorithm for preliminary design procedure for development the object for the modular ramp for aircraft loading application is shown in Figure 2.6 below.

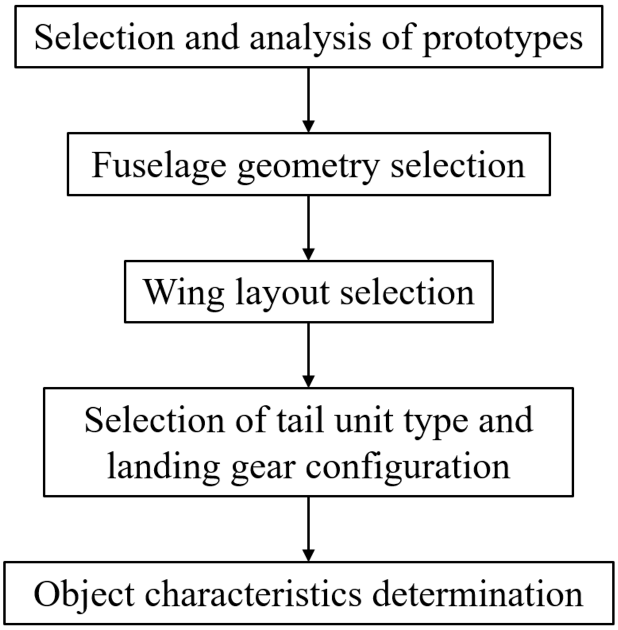

Figure 2.6 – An algorithm for preliminary design procedure

As the result preliminary design of freighter will be developed, so that modular ramp may be applied and investigated with determination of all required operational characteristics and disadvantages. The procedure of preliminary design shown and described in following section.

Conclusion to the part 2

To solve the problem of the facilitating the process of cargo aircraft loading by the new module ramp the following methods and procedures have been selected:

1. Software CATIA V5 for 3D modeling of the proposed concept.
2. FEM stress-strain analysis by ANSYS software application.
3. Standard components of the aircraft preliminary design.

The selected methods and procedures allow solving the main tasks of the thesis. The use of several specific software allows obtaining the most accurate final parameters of the desired modular ramp and optimizing its design where necessary. As a result, the preliminary design procedure made it possible to obtain required object for application and investigation of the modular ramp.

To meet requirements of the Environmental protection and Labor protection the procedures developed by the Department of Ecology and Department of Civil and Industrial Safety were applied.

3 PRELIMINARY AIRCRAFT DESIGN AS AN OBJECT FOR RESEARCH AND DEVELOPMENT RESULTS IMPLEMENTATION

The analysis of planes-analogous is a mandatory part of the preliminary design stage. Creation of the aircraft layout consists from composing the relative disposition of its parts and constructions, and all types of the loads (cargo, fuel, and so on). Choosing the scheme of the composition and aircraft parameters is directed by the best conformity to the operational requirements.

3.1 Choice of the projected data

The selecting of the optimum design parameters of the aircraft is based on the analysis of planes of close or same category, i.e. the cargo planes like AN-70, Airbus A400M, C-130J-30, Shaanxi Y-9.

The parameters found in the technical descriptions, Internet resources, as well as discussed at lectures on Aircraft Design and Strength course are shown in the table 3.1.

Table 3.1 – Operational-technical data of prototypes

Parameters	Planes			
	An-70	Airbus A400M	C-130J-30	Shaanxi Y-9
1	2	3	4	5
Max payload, kg	47000	37000	21800	25000
Crew, persons	3-5	2-4	2	4
Wing loading, kN/m^2			4.25	
Flight range with $G_{payload,max}$, km	1200	3300		
Range of cruising altitudes, km	12	11.3	12.3	10.5
Power/weight ratio, kWt/kg		4.41	4.53	
Specific fuel consumption, gt/km	0.174	0.238		
Number of engines and their type	4 Turboprop	4 Turboprop	4 Turboprop	4 Turboprop
Take off power, kW	4*13880	4*11000	4*4700	4*4250
Spec. fuel cons., take off, kg/kN	0.170			

Continuation of table 3.1

1	2	3	4	5
Pressure ratio	20.4	25	16.6	
Take off run distance, m	600	900	1433	
Landing run distance, m	600	900	777	
Take off distance, m	600	900		
Landing distance, m	600	900		
Take off gross mass, kg	137000	141000	74400	77000
Landing mass, kg	117000			
Wing span, m	44.06	42.4	39.7	38.015
Sweepback angle at ¼ of the chord, °		15	0	
Wing aspect ratio			10.1	
Wing taper ratio	2.625			
Fuselage length, m	40.73	45.10	34.69	33.109
Fuselage diameter, m	5.6			
Fuselage fineness ratio			7.01	
Cargo cabin width, m	4.8	4	3.1	3.5
Cargo cabin length, m	22.4	17.7	12.2	13.5
Cabin height, m	4.1	3.8	2.7	2.6
Cabin volume, m^3			128.9	
Horizontal tail span, m		18		
Horizontal tail sweepback angle, °	30			
Vertical tail height, m	16.38			
Vertical tail sweepback angle, °	20			
Landing gear base, m	18100			
Landing gear track, m			4.34	

The design of aircraft is developed according to the positioning of different parts of it and this leads to the unique formation of the aerodynamic characteristics. Aerodynamic and operational characteristics of the aircraft depends on the aircraft layout and aerodynamic scheme of the aircraft (Appendix A).

The airplane is a multipurpose ground all-aerodrome, close-and mid-range, four-engine, turbo-prop, single-fuselage, subsonic, middleweight transport, freighter.

The feature of the aircraft is its suitability for operation in a variety of climatic conditions, especially in a hot climate, in high altitude and unprepared aerodromes. Operation of the airplane in the transport version, provides complete autonomy when based on weak and unprepared aerodromes due to the built-in loading / unloading complex and the use of an auxiliary power plant.

Fuselage is half-metal, half-composite, beam-stinger, semi-monocoque construction. The fuselage is technologically divided into three parts: the front (11 formers), the middle (12 to 40 formers) and the caudal plumbing fixture compartment (from 41 former). Most elements of the fuselage construction are made of sheet and profiled duralumin.

The front compartment is airtight. There is a cabin of the crew, between 1 and 7 bulkheads. Behind it is a partition from the door to the cargo cabin. Nose of a fuselage, up to 1 former, not airtight, in it the placed radar antenna is closed by a radio-transparent railing. Under the cabin of the crew is a compartment of the front leg of the landing gear. Between 5 and 7 formers in the left side is a navigator blister. On the right side, between 7 and 10 formers, there are front doors. In the front part there are two emergency hatches: the upper one, for leaving the cabin with forced landing without a landing gear or on the water, is in the cabin of the crew, and the lower one, for leaving the airplane in the air, is located at the front door.

The middle part of the fuselage is airtight, with a cargo cabin. On both sides of the cabin, there are four rounded windows. There is a monorail on the ceiling, which moves a telpher. The telpher is intended for loading and unloading works. Between 33 and 45 formers there is a cargo hatch. The hatch is closed by a ramp at the end of which there is a wedge-shaped hitch and a rear hinge, which is attached with frame to 45 former. When opening the ramp can take two positions: position for loading / unloading wheeled vehicles, parachutists, wounded, etc., and also the ramp can deflect under the fuselage for parachute landing during the flight or for convenient loading, for example, directly from the truck bed. The cavity plunger mounting compartment is not sealed. In the middle there are units of navigational and aeronautical and radio equipment.

The wing is sweptback and has spar construction. It consists of two spars that go along the wing, ribs, stringers and skin.

Spars are attached to the load-carrying bulkheads of the fuselage. These spars transmit bending loads to them, so that it prevents from destruction of construction.

Ribs and stringers provide supercritical shape of the wing by the connection them with the skin. All of them sustain different loads in different directions from the direction of spars.

Leading edge and trailing edge of the wing are equipped with slats and flaps respectively.

Closely to the tip of the wing, there are ailerons on the trailing edge. They provide roll movement of the aircraft during the flight and are operated reversibly to each other.

The wing is also equipped with spoilers, which are located straightly in front of flaps. The spoilers are intended for reducing the lift and for helping ailerons during roll control.

Also, the wing is equipped with electrical anti-icing system that is intended for prevention of forming the ice on the leading edge of the wing, because it can lead to the blocking of movement of control surfaces.

Due to the high-wing configuration, aircraft has advantage during landing on not prepared runaway as well as during emergency landing (for example ditching).

The wing is equipped with winglets that provide better performance during take-off, cruise flight and landing. It prevents the intermixing of airflows from upper and lower part of the wing, which can be the cause of appearance of turbulent flow.

Below the wing there is four TP400 engines. The Europrop International TP400-D6 is an 11000 kW power plant, developed and produced by Europrop International for the Airbus A400M Atlas military transport aircraft. The TP400 is the most powerful single-rotation turboprop. It is perfect modern turboprop engine for designed freighter.

The tail unit is swept-back angled and T-shaped. It consists of horizontal and vertical stabilizers with primary control surfaces on each of them.

Horizontal stabilizer is equipped with elevator for motion around pitch axis, and vertical stabilizer provide the motion of aircraft around the vertical axis with the help of rudder. So that, pitch and yaw can be performed. Rudder consists of two parts, which attached to different hydraulic systems for safety.

The empennage has fixed tail construction with bolt-nut joining. This provide advantage in weight i.e. it is lighter than for example adjustable tail unit.

Body of tail unit with control surfaces are composite. It is give positive feature in weight, strength, corrosion resistance and reliability.

Airplane has tricycle landing gear configuration that provide good stability on the ground and better take-off and landing performance.

Nose landing gear is semi-articulated with two wheels. Shock absorber of nose landing gear has oleo-strut operation, which provides smoother operation during taxiing. The tires of nose landing gear are radial. Such type of tires results in lighter weight and provides improved performances. Nose landing gear retracts in forward direction that displaces the airplane center of gravity during flight.

Main landing gear is semi-articulated as well as nose one but it has twelve wheels: two wheels on each of six main landing gear struts. Each strut is equipped with oleo-strut shock absorber. The retraction of the main landing gear is carried out inside the landing gear compartment towards the center of the airplane. Struts of main landing gear are located behind the center of gravity of aircraft. This provides the stable position of the airplane while standing on the ground.

The aircraft has a steering control system of the wheels of the nose landing gear, which improves the maneuverability of the aircraft during taxiing. The steering of the wheels is controlled by deflecting the rudder pedals in the cockpit.

3.2 Aircraft layout and center of gravity calculation

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

Choosing the scheme of the composition and aircraft parameters is directed by the best conformity to the operational requirements.

3.2.1 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:

$$S_{wfull} = \frac{M_0 \cdot g}{P_0} \ (m^2), \tag{3.1}$$

where M_0 –take-off mass;

P_0 – wing loading.

$$S_{wfull} = \frac{163466 \cdot 9.81}{5438} = 227\ (m^2).$$

Wing span is:

$$l_w = \sqrt{S_{wfull} \cdot \lambda}\ (m), \tag{3.2}$$

where λ_w – wing aspect ratio.

$$l = \sqrt{227 \cdot 9.5} = 46.44\ (m).$$

Root chord is:

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

where η_w – taper ratio.

$$b_0 = \frac{2 \cdot 227 \cdot 3}{(1+3) \cdot 46.44} = 7.3\ (m).$$

Tip chord is:

$$b_t = \frac{b_0}{\eta_w}\ (m), \tag{3.4}$$

$$b_t = \frac{7.3}{3} = 2.4\ (m).$$

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

On the modern aircraft xenon double – or triple – longeron wing is used; longeron wing is common to the light sport, sanitary and personal aircrafts. Our aircraft has three longerons.

The geometrical method of mean aerodynamic chord determination was used (Appendix B). Mean aerodynamic chord is equal:

$$b_{MAC} = 5.27 \text{ (m)}.$$

After determination of the geometrical characteristics of the wing there is the estimation of the ailerons geometrics and high-lift devices.

Ailerons geometrical parameters are determined in next consequence:

Ailerons span:

$$l_{ail} = 0.375 \cdot \frac{l_w}{2} \text{ (m)}, \tag{3.5}$$

$$l_{ail} = 0.375 \cdot \frac{46.44}{2} = 8.7075 \text{ (m)}.$$

Aileron area:

$$S_{ail} = 0.065 \cdot \frac{S_{wfull}}{2} \text{ (m}^2\text{)}, \tag{3.6}$$

$$S_{ail} = 0.065 \cdot \frac{227}{2} = 7.38 \text{ (m}^2\text{)}.$$

Maximum wing width is determined in the forehead i-section and by its span is equal:

$$b_i = C_t \cdot b_w \text{ (m)}, \tag{3.7}$$

$$b_i = C_t \cdot b_w = 0{,}255 \text{ (m)}.$$

Chord of aileron:

$$C_{ail} = 0.25 \cdot b_i \text{ (m)}, \tag{3.8}$$

$$C_{ail} = 0.25 \cdot 2.55 = 0.6375 \text{ (m)}$$

Increasing of l_{ail} and C_{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 C_{ail} increase, the width of the xenon decreases.

3.2.2 Fuselage layout

During the choice of the shape and the size of fuselage cross section it is needed to come from the aerodynamic demands (streamlining and cross section).

Applicable to the subsonic cargo aircrafts (V <800 km/h) wave resistance doesn't affect it. It is required 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 transonic airplanes fuselage nose part has to be:

$$l_{fnp} = 2.1 \cdot D_f \text{ (m)}, \tag{3.9}$$

$$l_{fnp} = 2.1 \cdot 5.6 = 11.76 \text{ (m)}.$$

Except aerodynamic requirements consideration during the choice of cross section shape, it is required to consider the strength and layout requirements.

For ensuring of the minimal weight and minimal fuselage skin width the most convenient fuselage cross section shape is circular cross section.

To geometrical parameters concerned: 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 equal:

$$l_f = \lambda_f \cdot D_f \text{ (m)}, \tag{3.10}$$

$$l_f = 7.27 \cdot 5.6 = 40.47 \text{ (m)}.$$

Fuselage nose part aspect ratio is equal:

$$\lambda_{fnp} = \frac{l_{fnp}}{D_f}, \quad (3.11)$$

$$\lambda_{fnp} = \frac{19.94}{11.76} = 2.1.$$

Length of the fuselage rear part is equal:

$$l_{frp} = \lambda_{frp} \cdot D_f \text{ (m)}, \quad (3.12)$$

$$l_{frp} = 3.56 \cdot 5.6 = 19.94 \text{(m)}.$$

During the determination of fuselage length it is required to find approach minimum mid-section S_{ms} from one side and layout demands from the other.

For cargo airplanes fuselage mid-section first of all comes from the size of 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 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. It is required 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 500...550mm, depends on the fuselage type.

3.2.3 Layout and calculation of basic parameters of tail unit

One of the most important tasks of the aerodynamic layout is the choice of tail unit 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.

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

Where $m^{C_y}{}_x$ –is the moment coefficient; $x_{T.}$ x_F- center of gravity and focus coordinates. If $m^{C_y}{}_x=0$, than the plane has the neutral longitudinal static stability, if $m^{C_y}{}_x>0$, 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 it may be foundd 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 equal:

$$S_{VTU} = 0.25 \cdot S_w \ (m^2), \tag{3.13}$$
$$S_{VTU} = 0.25 \cdot 2225 = 50.51 \ (m^2)$$

Area o horizontal tail unit is equal:

$$S_{HTU} = 0.276 \cdot S_w \ (m^2), \tag{3.14}$$
$$S_{HTU} = 0.276 \cdot 227 = 62.65 \ (m^2).$$

Values L_{htu} and L_{vtu} depend on some factors. First of all their value are influenced by: the length of he nose 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:

$$S_{el} = 0.27 \cdot S_{HTU}\ (m^2), \tag{3.15}$$

$$S_{el} = 0.27 \cdot 62.65 = 16.92\ (m^2).$$

Rudder area:

$$S_{rud} = 0.24 \cdot S_{VTU}\ (m^2), \tag{3.16}$$

$$S_{rud} = 0.24 \cdot 50.51 = 12.12\ (m^2).$$

Choose the area of aerodynamic balance.

$0.3 \leq M \leq 0.6$

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

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

Elevator balance area is equal:

$$S_{eb} = 0.27 \cdot S_{HTU}\ (m^2), \tag{3.17}$$

$$S_{eb} = 0.27 \cdot 62.65 = 16.92\ (m^2).$$

Rudder balance area is equal:

$$S_{rud} = 0.24 \cdot S_{vtu} (m^2), \tag{3.18}$$

$$S_{rud} = 0.24 \cdot 50.51 = 12.12\ (m^2).$$

The area of altitude elevator trim tab:

$$S_{te} = 0.08 \cdot S_{el}\ (m^2), \tag{3.19}$$

$$S_{te} = 0.08 \cdot 16.92 = 1.36\ (m^2).$$

Area of rudder trim tab is equal:

$$S_{tr} = 0.06 \cdot S_{rud}\ (m^2), \tag{3.20}$$

$$S_{tr} = 0.06 \cdot 12.12 = 0.727\ (m^2).$$

Span of horizontal tail unit:

$$\mathrm{l_{HTU}} = 0.4 \cdot \mathrm{l_w}\ (\mathrm{m}), \tag{3.21}$$

$$\mathrm{l_{HTU}} = 0.4 \cdot 46.44 = 18.58\ (\mathrm{m}).$$

Span of vertical tail unit:

$$\mathrm{l_{VTU}} = 0.165 \cdot \mathrm{l_w}\ (\mathrm{m}), \tag{3.22}$$

$$\mathrm{l_{VTU}} = 0.165 \cdot 46.44 = 7.66\ (\mathrm{m}).$$

Tip chord of horizontal stabilizer is:

$$\mathrm{b_{tip}^{HTU}} = \frac{2 \cdot \mathrm{S_{HTU}}}{(\eta_{\mathrm{HTU}} + 1) \cdot \mathrm{l_{HTU}}}\ (\mathrm{m}), \tag{3.23}$$

$$\mathrm{b_{tip}^{HTU}} = \frac{2 \cdot 62.65}{(2.92 + 1) \cdot 18.58} = 1.72\ (\mathrm{m}).$$

Root chord of horizontal stabilizer is:

$$\mathrm{b_{root}^{HTU}} = \eta_{\mathrm{HTU}} \cdot \mathrm{b_{tip}^{HTU}}\ (\mathrm{m}), \tag{3.24}$$

$$\mathrm{b_{root}^{HTU}} = 2.92 \cdot 1.72 = 5.02\ (\mathrm{m}).$$

Tip chord of vertical stabilizer is:

$$\mathrm{b_{tip}^{VTU}} = \frac{2 \cdot \mathrm{S_{VTU}}}{(\eta_{\mathrm{VTU}} + 1) \cdot \mathrm{l_{VTU}}}\ (\mathrm{m}), \tag{3.25}$$

$$\mathrm{b_{tip}^{VTU}} = \frac{2 \cdot 50.51}{(1 + 1) \cdot 7.66} = \frac{113.5}{15.32} = 6.6\ (\mathrm{m}).$$

Root chord of vertical stabilizer is:

$$\mathrm{b_{root}^{VTU}} = \eta_{\mathrm{VTU}} \cdot \mathrm{b_{tip}^{VTU}}\ (\mathrm{m}), \tag{3.26}$$

$$\mathrm{b_{root}^{VTU}} = 1 \cdot 6.6 = 6.6\ (\mathrm{m}).$$

3.2.4 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: $B_m = (0.15 \dots 0.2) b_{MAC} = 0.17 * 5.26254 = 0.9\, m$

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:

$$\mathrm{B} = 0.44 \cdot \mathrm{L_f}\ (\mathrm{m}), \tag{3.27}$$

$$\mathrm{B} = 0.44 \cdot 40.47 = 17.8\ (\mathrm{m}).$$

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

Front wheel axial offset will be equal:

$$\mathrm{B_n} = \mathrm{B} - \mathrm{B_m}\ (\mathrm{m}), \tag{3.28}$$

$$\mathrm{B_n} = 17.8 - 0.9 = 16.9\ (\mathrm{m}).$$

Wheel track is:

$$\mathrm{T} = 0.3243 \cdot \mathrm{B}\ (\mathrm{m}), \tag{3.29}$$

$$\mathrm{T} = 0.3243 \cdot 16.9 = 5.48\ (\mathrm{m}).$$

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.

$$\mathrm{H_{cg}} = 0.09 \cdot \mathrm{D_f}\ (\mathrm{m}), \tag{3.30}$$

$$\mathrm{H_{cg}} = 0.09 \cdot 5.6 = 0.504\ (\mathrm{m}).$$

Wheels for the landing gear is chosen by the size and run loading on it from the takeoff weight; for the front support it is considered 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. Breaks are installed 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 equal:

$$P_n = \frac{B_m \cdot M_0 \cdot 9.81 \cdot K_g}{B \cdot z} \text{ (N)}, \tag{3.31}$$

$$P_n = \frac{0.9 \cdot 163466 \cdot 9.81 \cdot 1.7}{17.8 \cdot 2} = 68919 \text{ (N)}.$$

Main wheel load is equal:

$$P_m = \frac{(B - B_m) \cdot M_0 \cdot 9.81}{B \cdot n \cdot z} \text{ (N)}, \tag{3.32}$$

$$P_m = \frac{(17.8 - 0.9) \cdot 163466 \cdot 9.81}{17.8 \cdot 6 \cdot 2} = 126877 \text{ (N)}.$$

Table 3.2 – Aviation tires for designing aircraft

Main gear		Nose gear	
Tire size	Ply rating	Tire size	Ply rating
1016×355.6mm	24	1016×355.6mm	24

3.2.5 Choice and description of power plant

The TP400 is the most powerful single-rotation turboprop engine developed and produced by Europrop International. Delivering an output of more than 11,000 shaft horsepower at sea level and a three-shaft configuration combining state-of-the-art engine modules. To optimize engine utilization and enable post-flight troubleshooting, the engine benefits from a dual Full Authority Digital Engine Control (FADEC). Have possibility of operating up to 40,000 ft. Interchangeable modules improve engine availability for operational support and efficiency for all maintenance activities. And very important thing – it is first military engine to be fully civil certified from the outset by EASA in 2011. [5]

General characteristics:

Type: turboprop;

Length: 3.5 m (137.8 in);

Diameter: 5.30 m (17.39 ft; 530 cm; 208.7 in);

Dry weight: 1,890 kg (4,166.7 lb).

Components: five stage intermediate pressure compressor, with no variable stators and a six stage high pressure unit with two rows of variables; single stage high pressure and intermediate pressure units, three stage power turbine.

Performance:

Maximum power output: 11,000 kW;

Overall pressure ratio: 25;

Specific fuel consumption: 0.238 kg/kW-hr (0.39 lb/shp-hr) approx.;

Power-to-weight ratio: 4.41 kW/kg (2.68 hp/lb).

3.2.6 Determination of the mass power 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 2.3.

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 2.3.

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

$$X_w^{/} = \frac{\Sigma m_i^{/} X_i^{/}}{\Sigma m_i^{/}} \text{ (m).}$$

Table 3.3 – Trim shet of equipped wing masses

N	Name	Mass		Coordinates of C.G. (m)	Moment (kgm)
		Units	total (kg)		
1	2	3	4	5	6
1	Wing (structure)	0,01	16168,42	2,37	38289,14
2	Fuel system, 40%	0,005	866,37	2,37	2051,69
3	Control system, 30%	0,001	201,06	3,16	634,86
4	Electrical equip. 10%	0,003	411,93	0,53	216,78
5	Anti-icing system 50%	0,006	997,14	0,53	524,75
6	Hydraulic system, 70%	0,009	1384,56	3,16	4371,77
7	Engine	0,19	31307,01	0	0
8	Equipped wing	0,31	51336,5	0,9	46088,99
9	Nose landing gear	0,004	645,2	-11,07	-7141,55
10	Main landing gear	0,04	5806,8	2,63	15279,27
11	Fuel	0,18	28951,47	1,32	38089,56
12	Equipped wing	0,53	86739,96	1,07	92316,27

3.2.7 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 2.4.

The CG coordinates of the FEF are determined by formulas:

$$X_f^{/} = \frac{\Sigma m_i^{/} X_i^{/}}{\Sigma m_i^{/}} \text{ (m)},$$

$$Y_f^{/} = \frac{\Sigma m_i^{/} Y_i^{/}}{\Sigma m_i^{/}} \text{ (m)}.$$

It can be found fuselage center of gravity coordinate $\mathbf{X_f}$ by divided sum of mass moment of the fuselage ($m_i^{'}$, X_i) on sum of total mass of fuselage ($m_i^{'}$):

$$X_f = \sum m_i \bullet X_i / \sum m_i = 23{,}553 \text{ (m)}.$$

Aircraft fuselage centering of gravity masses drawing which is presented in (Appendix C).

After the center of gravity (CG of FEW) and fuselage parameters determined, the moment equilibrium equation can be constructed relatively fuselage nose:

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

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

$$X_{MAC} = \frac{m_f * x_f + m_w * x_w - m_0 * c_n}{m_0 - m_w} \text{ (m)},$$

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.

$$X_{MAC} = 17.4138 \text{ (m)}.$$

Table 3.4 – Trim sheet of equipped fuselage masses

N	Objects	Mass		Coordinates of C.G. (m)	Moment (kgm)
		Units	Total (kg)		
1	2	3	4	5	6
1	Fuselage	0,1	16245,3	20,24	328723
2	Horizontal tail unit	0,012	1856,98	38,59	71661
3	Vertical tail unit	0,013	2141,41	41,45	88760
5	Radar equipment	0,003	539,44	2,02	1091
6	Instrument panel	0,006	931,76	2,43	2262,5
7	Air-navigation system	0,005	800,98	4,05	3241,6
8	Radio equipment	0,003	392,32	3,28	1270,2
9	Cargo compartment equipment	0,032	5230,9	16,19	84678
10	Control system, 70%	0,003	469,15	24,28	11392
11	Electrical equipment, 70%	0,027	3707,4	16,19	60016
12	Hydraulic system, 30%	0,004	593,38	24,29	14409
13	Heat and sound isolation	0,005	833,68	8,1	6747,7784
14	Duty load	0,008	1283,21	20,25	25966

Continuation of table 3.4

1	2	3	4	5	6
15	Air conditioning system equipment	0,003	398,86	8,1	3228,4
16	Anti-icing system, 30%	0,004	598,29	20,24	12106,3
17	Additional equipment	0,0002	32,7	20,24	661,55
18	Auxiliary power unit	0,003	474,1	21,5	10192,1
19	Untypical eq.	0,001	196,16	20,235	3969,3
20	Commercial load	0,25	40000,13	18,22	728462
21	Total	0,47	76726,1	19,02	1458836
	Checking	1	163466		

3.2.8 Calculation of center of gravity positioning variants

The list of mass objects for center of gravity variant calculation given in Table 2.4 and Center of gravity calculation options given in table 2.5, 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
Equipped wing without fuel and L.G.	51336,5	18,3	940052
Nose landing gear (retracted)	645,2	7,36	4739
Main landing gear (retracted)	5806,81	17,05	98977,3
Fuel	28951,5	18,73	542244,3
Equipped fuselage	36726	19,89	730374,2
Payload	40000	18,21	728462,4
Nose landing gear (opened)	645,2	10,35	6674,64
Main landing gear (opened)	5806,8	18,05	104784,12

Table 3.6 – Airplanes C.G. position variants

N	Name of objects	Mass, kg	Moment, kgm	C.G. m	Centering,%
1	Take-off mass (L.G. opened)	163466	3052591,75	18,68	23,95
2	Take-off mass (L.G. retracted)	163466	3044849,34	18,63	23,05
3	Landing variant (L.G. opened)	135145,68	2522168,4	18,67	23,73
4	Transportation variant (without payload)	123465,9	2316387	18,76	25,61
5	Parking variant (without fuel and payload)	94514,41	1781885,05	18,85	27,35

Conclusion to the part 3

As a result of the analysis of aircraft prototypes, a choice of the main characteristics of the designing aircraft and brief description of all parts of the aircraft were performed. The engines which meet the requirements for the designed aircraft was selected. The aircraft layout reflects main features of contemporary transport aircraft.

The center of mass position characteristics was determined. Also the mass position of the main parts of the aircraft and main equipment and furnishing by its distance from the main aerodynamic chord were checked. After designing of the wing and the fuselage the calculations of the center of gravity of the equipped aircraft was made.

The result of part are data and characteristics for preliminary design of aircraft as object for module ramp for aircraft loading application.

4 RESULTS AND DISCUSSIONS

4.1 Creation of 3D parts in CATIA V5

The creation of modular ramp for aircraft loading begins from ramp sections. These elements located between supports and create a platform for vehicle movement. Ramp section consist of four beams that shrink in cross section to the edges. The edges are tubes with hole for pin connection. Beams and tubes form a one-piece structure. Each third of the length is transversely reinforced with small plates between beams. And since wheeled vehicles will move on the structure, rough elements were added on top of the beams (Figure 4.1). In the case of the operation of the ramp with vehicle with small wheels, a sheet of metal with numerous bulges over its area can be installed on top of the beams.

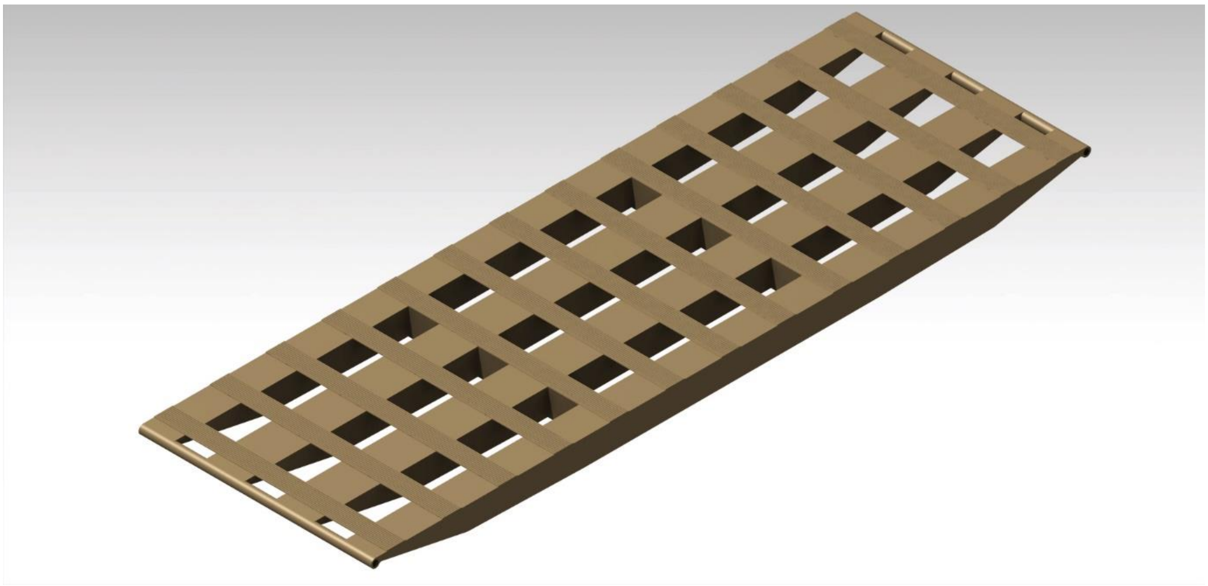

Figure 4.1 – Ramp section

Main elements of the modular ramp is supports. They take to themselves functions of regulation of height, connection of ramp elements and support of them, of course. So according to part 1.3 described requirements each support created in two main parts – upper and lower (Figure 4.2). Lower part consists of two sustainable stands connected together with narrow trapezoidal square beam. The mating holes for upper part are square sections with holes for pin connection. In its turn upper part has two square sections to shove into mating holes of lower pins. Mating pattern of holes for pins locates on these sections and it take over function of height regulation.

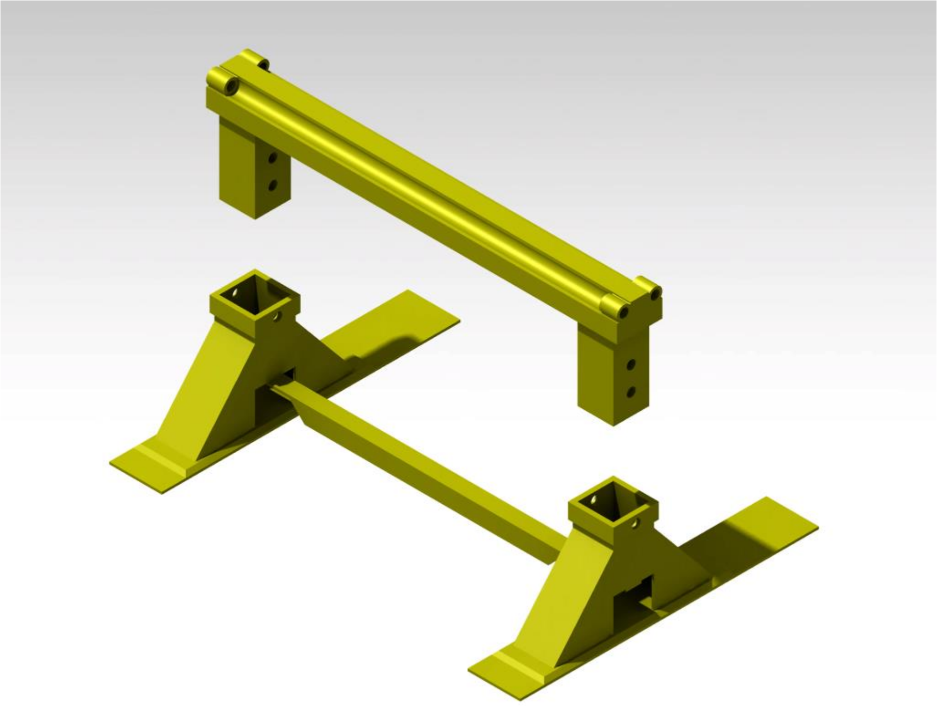

Figure 4.2 – Upper and Lower parts of support

The highest construction element of upper part is ramp pad. It provides connection of ramp elements. Places for pin intake have concave form with some radius and eyelet for pins connection on the sides (Figure 4.3). Concave groove required for safety in case of pin cutting by shear moment. In such situation ramp part with tubular edges that connected to support dropped in provided concave groove.

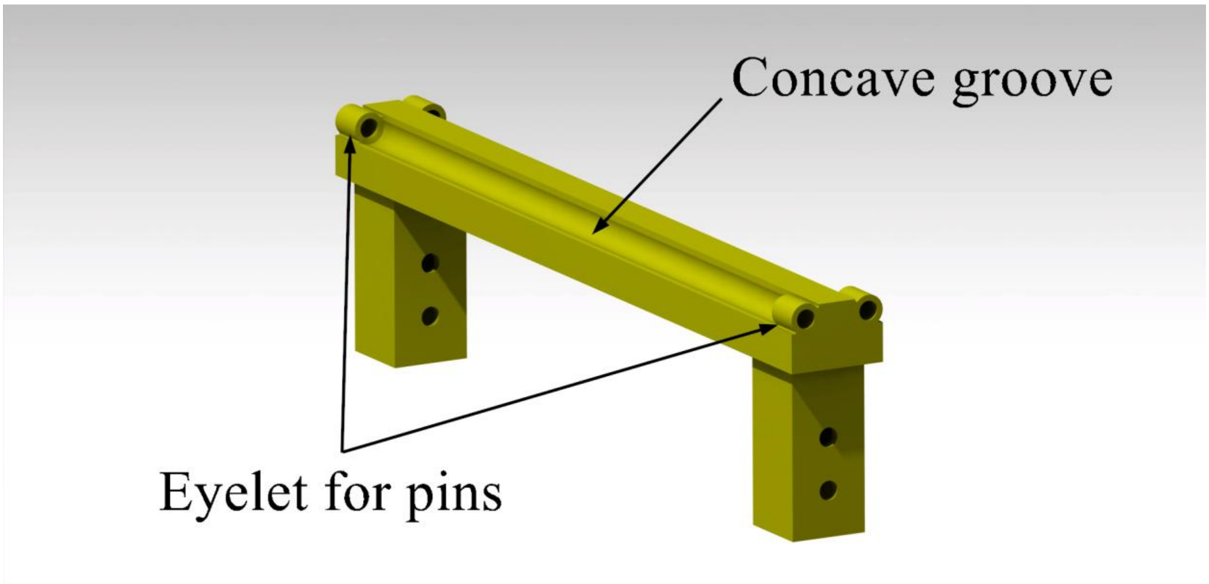

Figure 4.3 – Support upper part pad elements

The last elements of modular ramp are the ramp pad, wedge, and lead up ramp (Figure 4.4). The pad is modeled in the same way as pad for supports with concave form with some radius and eyelet for pins connection on the sides. Only difference that it has own stand and should be located on the ground as the first connection element between wedge or lead up and ramp section. The wedge and lead up ramp are element that provide ramp entrance and ramp exit. The wedge has sharper approach angle and the lead up respectively is flatter. Both ending parts created per analogical way as ramp section – four beams of required form, tube on one edge connects beams together and provide connection part for pin and rough elements for grip. Another edge connected with stand plate provided to lay on the ground.

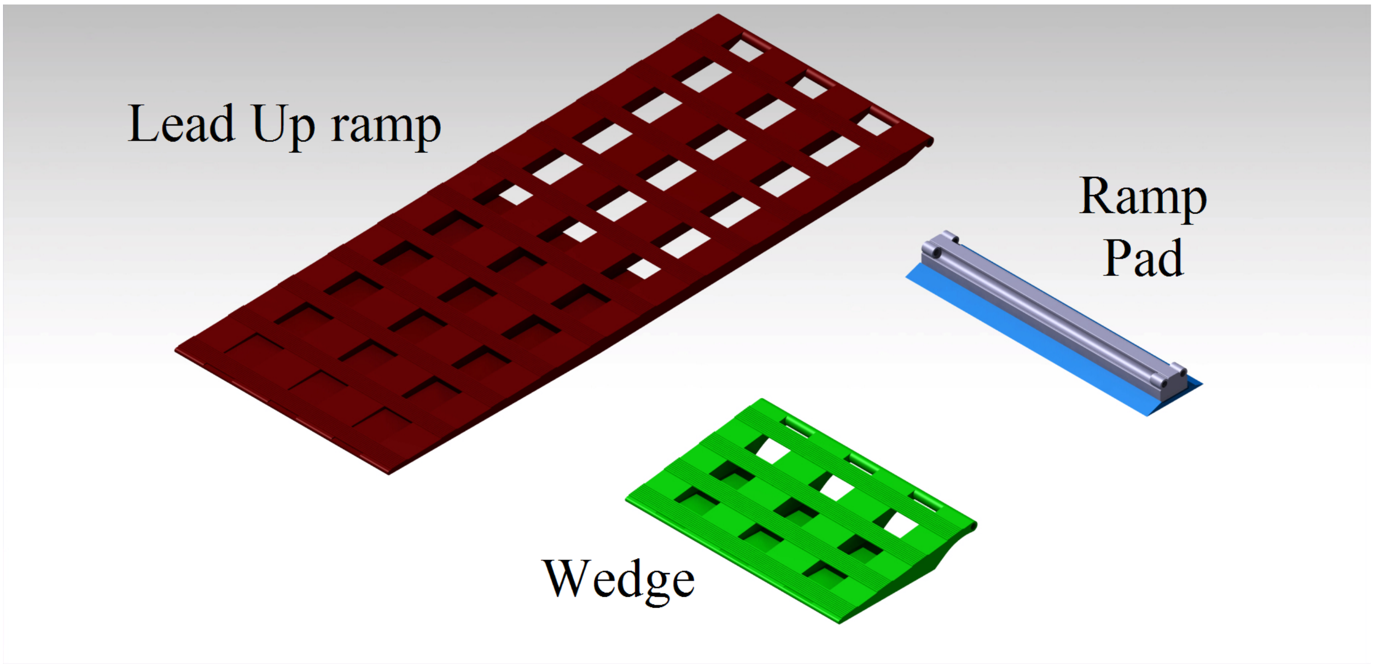

Figure 4.4 – Entrance elements of the ramp and ground ramp pad

The pins for the connections were taken with a circular cross section with a diameter 19 mm or 0.75 inches. For supports it is required two short pins and two long for support height fixation and ramp sections connection correspondently.

All parts has wall thickness of sections in 5 mm and width – 760 mm.

So finally modular ramp consist of next parts with next geometrical parameters:

- Three supports with adjustable height – 33 - 38 cm, 43 - 58 cm, 56 – 81 cm correspondently;
- Ramp section with length 240 cm;

- Lead up ramp with length 140 cm;
- Ramp pad and wedge that has height about 8 cm;
- Steel pins of two size.

4.2 FEM analysis under required load

4.2.1 Maximum load for preliminary designed modular ramp

Empirically it has been determined that the most stressful part of the ramp is ramp section connected between two supports located on different height. For such case load may be applied to the center or with offset to the side of ramp according to longitudinal axis. When load acts with significant offset from center it cause torsional moment which in turn increases the perceived load. After first FEA analysis in Ansys results were obtained. So maximum load that can act on center of ramp section which is normal operation condition in approximate contact patch of wheel is 3.7 tons or 37 kN and with the same disposition of load on the side maximum load is equal 3 tons or 30 kN. It should be taken into account that yield strength for aluminum alloy is 280 MPa and above loads cause stresses approximately equal to 280 MPa. And the most stressful places of unit are transitions from beams to tubes of the edges (Figure 4.5). Supports under such loads show maximum stress about 60 MPa and this means supports has not bad margin of strength for larger loads.

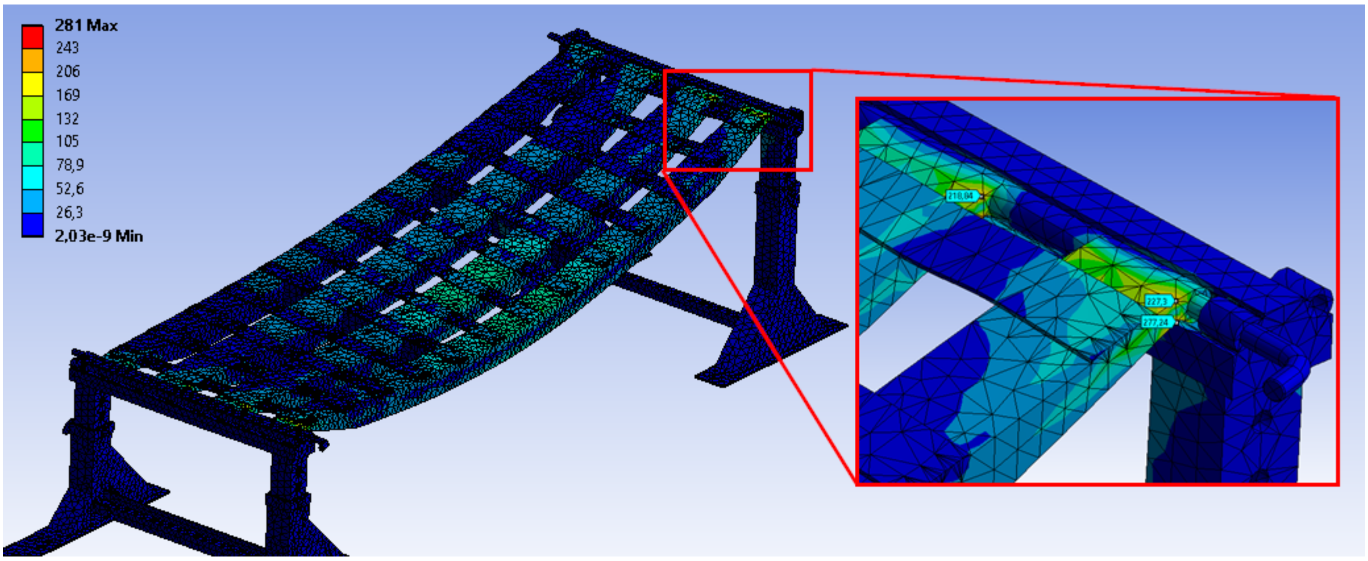

Figure 4.5 – Stress concentrating points of ramp unit under load acting on the side

4.2.2 Determination of required maximum load

Preliminary design of freighter was developed, so that modular ramp may be applied and investigated with determination of all required operational characteristics and disadvantages. Fuselage diameter D_f is equal to 5.6 m and cargo cabin of designed freighter has characteristics about 4.2 m in height, 4 m in width and 19 m in length. Large commercial vehicles like tourist bus or even tow truck with semi-trailer are possible to be loaded and transported by freighter with such cargo cabin dimension. Something like military technique (Hammers or tanks) is not considered because they are usually designed to operate in complicated conditions, so ramp entry angle at ramp crest should not be an obstacle for them. So the most required examples for analysis are semi-trailers, busses and even helicopters.

One of the biggest applicable vehicle for designed cargo cabin is tow-truck with semi-trailer. Its height is up to 4 m and length about 18 - 19 m. Modern common truck with trailer has five axis – two for truck and tree for trailer, and permissible weight up to 40 tons with cargo. The load of its semi-trailer on the axles grouped in the rear of the trailer in the amount of three act with a weight of about 25 tons and running ahead this is the load that the designed ramp cannot withstand by supports in any way without a complete redesign. So empty truck with trailer was considered. Empty common European truck and trailer act with loads per axle shown in Figure 4.6. It can be noted that maximum load per one axle is equal approximately 6000 kilos or 6 tons. So one wheel will be act on ramp section with load about 3 tons or approximately 30 kN.

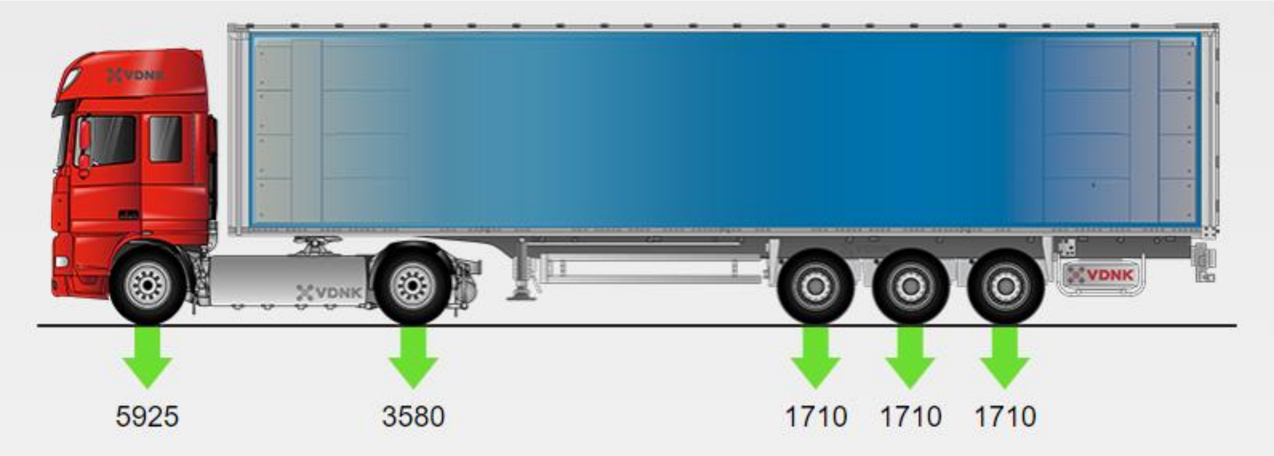

Figure 4.6 – Empty tow-truck with semi-trailer loads distribution per axle

As was described in previous subsection preliminary design of ramp has maximum load of 3 tons at worst and that is for safety factor (SF) equal to 1. When, for example, large tourist bus with big overhang will be considered its weight is around 14 - 16 tons and maximum load per axle will be about 9 tons. This is because of its weight uneven distribution between axles – approximately 55% to 45%. So one of ramp section in this case should be able to operate under load in 4.5 tons or 45 kN.

SF is a value showing the ability of a structure to withstand loads applied to it above the calculated. It is defined as the ratio between the strength of the material and the maximum stress in the part and has next formula:

$$\mathrm{SF} = \frac{\sigma_l}{\sigma_{\mathrm{cal}}}, \tag{4.1}$$

where σ_l – material tensile strength,

σ_{cal} – maximum calculated stress.

As was mentioned aluminum alloy tensile strength is equal to 280 MPa and for safety is it required to take SF coefficient equal to 1.2 - 1.3. From the formula (4.1) maximum calculated stress determined:

$$\sigma_{\mathrm{cal}} = \frac{\sigma_l}{\mathrm{SF}} \text{ (MPa)}$$

$$\sigma_{\mathrm{cal}} = \frac{280}{1.2..1.3} \approx 215..230 \text{ (MPa)}$$

So required loads and characteristics was determined:

- Load per axle up to 9 - 10 tons and from this 4.5 - 5 tons or 45 - 50 kN per one wheel;
- Maximum calculated stress about 215 - 230 MPa;
- Safety factor coefficient about 1.2 - 1.3.

Per previously analysis and calculation ramp section needs to be optimized and improved for required parameters in its stress concentrating points (Figure 4.5).

4.2.3 Optimization and improving of modular ramp

The most stressful places of unit are transitions from beams to tubes of the edges. This transitions have small radius thus when load acting on the ramp section big amount of stress concentrate at point of transitions and need to remember that there are no smooth transitions between faces of beam because the simplest possible cross-section was used.

To decrease value of stress ant stress concentrators radius of transitions from beams to tubes of the edges should be increased. Radius between beams to tube was increased in 6.5 times and curvature itself was moved lower to align distribution of stresses under loading (Figure 4.7).

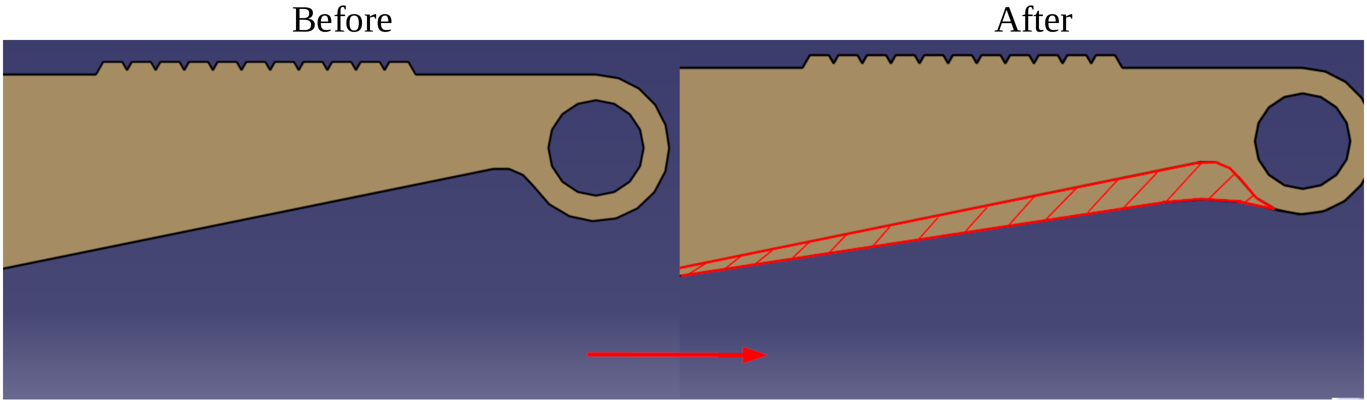

Figure 4.7 – Ramp section improving

After compering results with the first analysis decreasing of stress took place from 270 MPa to 170 MPa under load of 3.7 tons or 37 kN at center of ramp section about the longitudinal axis and from 280 MPa to 220 MPa under load of 3 tons or 30 kN at disposition of load on the side with torsion moment. That is mean that stress is decreased on 37% and 21% respectively for both cases. An excellent result considering that the design changes did not cause any significant deterioration in weight or geometry. The only thing that was changed also is support upper part pads – them length not allow ramp section with improvements to deviate downward normally, so length was little bit decreased to remove the ledge that interfering downward deviation.

The first conclusion and recommendation can be drawn. Vehicle with weight over 6 tons per one axle should drive with wheels in the center of the ramp sections for correct load distribution and safety of operation.

Last step to check optimized design of ramp section is loading with the required parameters. Load in 5 tons or 50 kN was applied to ramp section and resultant stress was calculated. Stress concentrators for this case remained the same but maximum value is equal to 231 MPa (Figure 4.8). Completely satisfactory.

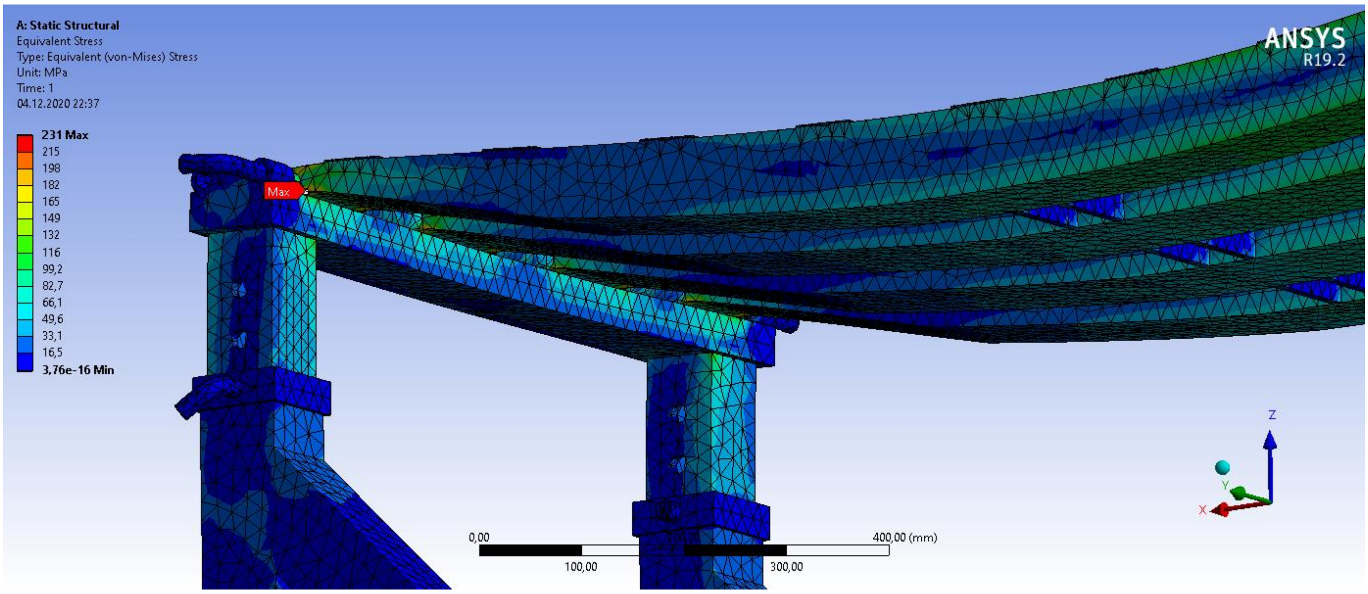

Figure 4.8 – Ramp section FEA analysis under 5 tons of load

That's mean that according to the formula (4.1) SF for the highest required load is equal:

$$\mathrm{SF} = \frac{280}{231}$$

$$\mathrm{SF} = 1.21$$

For load that is equal 4.5 tons or 45 kN stress value is equal to 208 MPa and SF according to formula (4.1) is next:

$$\mathrm{SF} = \frac{280}{208}$$

$$\mathrm{SF} = 1.35$$

Supports was also analyzed and the maximum load that could be carried by them is equal to 8 tons or 80 kN. Under such load the stress that the support is experiencing is equal to 226 kN. And safety factor for supports under 8 tons is next:

$$\mathrm{SF} = \frac{280}{226}$$

$$\mathrm{SF} = 1.24$$

It is acceptable and applicable for required operation conditions.

4.3 Final characteristics for module cargo ramp for aircraft loading

After all analysis, modifications and calculations final specifications was concentrate in table 4.1.

Table 4.1 – Specification of modular cargo ramp for loading aircraft

№	Part name	Geometrical characteristics (H×L×W), cm	Weight, kg	Max Capacity (per axle), kg
1	Wedge	8 × 50 × 76	13.2	10000
2	Ramp Section	8.5× 235 × 76	53.8	
3	Lead-Up Ramp	4 × 193 × 76	44.2	
4	Support 33-38	33-38 × 63 × 87	16.5	16000
5	Support 43-58	43-58 × 71 × 87	21.0	
6	Support 56-81	56-81 × 61 × 87	22.3	
7	Ramp Pad	8 × 20 × 86	9.12	

From the previous subpart and table 4.1 next final characteristics and requirements for operations of designed modular cargo ramp for loading aircraft can be concluded:

- Vehicle with weight up to 6 tons per axle can operate without any restrictions;
- Vehicle with weight from 6 tons per axle up to 10 tons per axle can operate with wheel movement in the center of the ramp (resultant load of distributed load should acts on center section of the ramp);
- Vehicle with caterpillar tracks and length of contact patch less than 470 cm should has weight not more than 16 tons;

- Vehicle with weight or geometrical characteristics that not satisfy requirements described in previous points cannot be used with modular cargo ramp without any modifications or reinforcements.

Range of examples of vehicles that have possibility to operate with such modular ramp is very wide. It can be heavy-lift helicopter CH-47 Chinook with four landing gear struts located in the corners of its fuselage and with weight around 12 tons; bulldozer Cat D5R2 XL with tracks and weight up to 16 tons; numbers of busses, trailers, trucks, etc.

Conclusion to the part 4

Creation of 3D models in CATIA, analysis in ANSYS Workbench, determination of required characteristics, optimization and modification of structure and final specification of modular cargo ramp units for aircraft loading have been performed.

Result of the part is the modular cargo ramp that can operate with light, middle and large cargo aircrafts. Vehicle with weight up to 10 tons per one axle can be loaded and unloaded using designed cargo ramp. Designed equipment has possibility to be assembled in various configurations on height up to 81 cm. Height of support can be increased by using more long upper part of support.

Designed cargo ramp corresponds to all requirements that was described in part 1. It is easy in construction and as result easy to operate and manufacture, so low in cost. Weight of each part of the equipment gives possibility to operate with it by one-two person. And of course it is applicable to use this ramp not only for aircraft loading and unloading, so it is universal in its purpose.

5 LABOR PROTECTION

5.1 Analysis of harmful and dangerous production factors

Design engineers work on the development of aircrafts and various devices and equipment for them. Usually design engineers work at the computers in the office. Typical office room has 500-1000 m^2 area of working zone, where working 200-300 heads of engineers. Office building usually has developed air-conditioning and ventilation system and also developed lighting system with combined natural and artificial sources of light. However, working process in such conditions leads to dangerous and harmful production factors. Regarding to the ГОСТ 12.0.003-74 several main ones can be distinguished. So the following factors which an engineer may encounter while working at a computer in an office building can be noted:

- Increased or decreased air temperature of the working area;
- High or low humidity;
- Increased noise in the workplace;
- Lack or absence of natural light.

Continuing to refer to the ГОСТ 12.0.003-74, it may be indicated that by the nature of action these factors belong to the physical group of hazardous and harmful production factors. So let’s analyze basic provisions and requirements for each of factors regarding to specific standards.

Increased or decreased air temperature of the working area and high or low humidity can negatively influence on well-being, health and normal activity of engineer during work day. Temperature and humidity indicators should be optimal for comfort and safe working process. According to ДСаНПіН 3.3.2.007-98 in production facilities at workplaces with visual display terminals (VDT), optimal values of microclimate parameters should be ensured: temperature and relative humidity. These parameters regulated by ГОСТ 12.1.005-88. Common to current standard required values in computer rooms and other industrial premises, when performing operator-type work related to neuro-emotional stress, the optimum air temperature of 22-24 °C and its relative humidity of 60- 40%. When ensuring optimal microclimate indicators, the temperature of the internal surfaces of structures enclosing the working area (walls, floor, ceiling, etc.), or devices (screens, etc.), as well as the temperature of the outer surfaces of technological equipment or devices enclosing it should not go out by more than 2 °C beyond the optimal. When the temperature of the surfaces of the enclosing structures is below or above the optimal values of the air temperature, the workplaces should be removed from them at a distance of at least 1 m. The air temperature in the working area, measured at different heights and in different parts of the premises, should not go outside during the shift the optimal values.

Work at the computer is demanding on lighting. In case of lack or absence of natural light eyes can get tired during continual interaction with display and vision may deteriorate as result. For such case it is required to apply artificial lighting to placement of the work. According to ДСаНПіН 3.3.2.007-98 artificial lighting in rooms with workplaces equipped with VDT computers and PCs should be carried out by a system of general uniform lighting. In industrial and administrative-public premises, in the case of overwhelming work with documents, it is allowed to use a combined lighting system (in addition to the general lighting system, local lighting fixtures are additionally installed). The value of the illumination coefficient on the surface of the desktop in the area of document placement should be 300-500 lux. If these illumination values cannot be provided by the general lighting system, local lighting may be used. In this case, local lighting fixtures should be installed so as not to create glare on the surface of the screen, and the illumination of the screen should not exceed 300 lux. In the case of artificial lighting, predominantly LB-type fluorescent lamps should be used as light sources. In the case of providing reflected lighting in industrial and administrative-public premises, it is allowed to use metal halide lamps with a power of 250 W. It is allowed to use incandescent lamps in local lighting fixtures.

Increased noise in the workplace affects more than just concentration and performance. The stress that can be experienced in a noisy work environment can lead to cardiovascular disease and hypertension and also may influence on nervous system of person. According to ДСаНПіН 3.3.2.007-98 industrial premises for working with VDT (operator rooms, dispatch rooms) should not border on premises in which noise exceed permissible values (production shops, workshops, etc.) and sound insulation of fencing structures of rooms with VDT must provide noise parameters that meet the requirements according to ДСН 3.3.6.037-99.

So characteristics and permissible noise levels at workplace determined in ДСН 3.3.6.037-99. The characteristic of constant noise at workplaces are the sound pressure levels L in dB in octave bands with geometric mean frequencies of 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000 Hz. Permissible sound pressure levels in octave frequency bands, sound levels and equivalent sound levels at workplaces should be taken for broadband constant and non-constant (except impulse) noise according to the Table 5.1 and for tonal and impulse noise 5 dB less than the values indicated in the Table 5.1.

Table 5.1 – Sound pressure levels, sound levels and equivalent sound levels for workplaces in the premises - directorates, design offices; calculators, computer programmers, in laboratories for theoretical work and data processing, receiving patients in health centers.

Sound pressure levels, dB, in composite bands with geometric mean frequencies, Hz									Sound levels and equivalent sound levels, dB A
31,5	63	125	250	500	1000	2000	4000	8000	
86	71	61	54	49	45	42	40	38	50

The most significant negative harmful production factor is increased noise in the workplace. It can lead to serious health consequences. And it is difficult to maintain it at the required level at places like engineering office which is full of different electrical technique, air-conditioning systems and in some cases working premises located near shops, the sound from which can cause a lot of problems with noise regulation.

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

Often office room of design engineers located next to manufacturing shop. In such manufacturing shops main equipment is machine-tools. Let’s take machine-tool with the sound power level in the octave frequency band with a geometric mean frequency of 500 Hz that is equal 105 dB. And it is needed to determine the expected sound pressure level in the octave band of frequencies with a geometric mean frequency of 500 Hz, created during the operation of the machine, at the workplace near the production area. So typical office room area is 500 m^2 with dimensions in width a = 25 m, in length b = 20 m and in height c = 4 m. And distance from the noise source to the nearest workplace r = 30 m.

The obtained value of the sound pressure should be compared with the permissible level for permanent workplaces and work areas in production facilities in accordance with ДСН 3.3.6.037-99.

Based on the size, we find B_{1000} – the constant of the room at a geometric mean frequency of 1000 Hz, which is calculated depending on the size and type of the room. For rooms with a large number of people and upholstered furniture it is:

$$B_{1000} = \frac{V}{6}\,(m^2), \tag{5.1}$$

where V – is a volume of the room.

The constant of the room at a geometric mean frequency of 1000 Hz is:

$$B_{1000} = \frac{25 \cdot 20 \cdot 4}{6} = 333.3\ (m^2).$$

For a constant room B at a frequency of 500 Hz:

$$B_{500} = B_{1000} \cdot \mu\ (m^2), \tag{5.2}$$

where μ – frequency factor.

For room with V > 1000 m^3 frequency factor is:

$$\mu = 0.7.$$

The constant of the room at a geometric mean frequency of 500 Hz is:

$$B_{500} = 333.3 \cdot 0.7 = 233.3\ (m^2).$$

The expected octave sound pressure level L in dB at the workplaces of the room in which there is one noise source in the area of direct and reflected sound is determined by formula:

$$L = L_w + 10\lg\left(\frac{\chi\Phi}{S} + \frac{4\psi}{B}\right) \text{ (dB)}, \tag{5.3}$$

where L_w – octave sound power level of the noise source;

Φ – directional factor;

χ – empirical coefficient;

ψ – coefficient taking into account the violation of the diffuseness of the sound field;

S – area of an imaginary surface of regular geometric shape surrounding the source and passing through the workplace.

Area of an imaginary surface on the surface of a floor, wall, floor is:

$$S = 2\pi r^2 \text{ (m}^2\text{)}. \tag{5.4}$$

Without taking into account the directional factor of noise and violations of the acoustic diffuseness of the sound field in the room ($\Phi = 1$, $\chi = 1$, $\psi = 1$), obtained next:

$$L = 105 + 10\lg\left(\frac{1}{2\pi 30^2} + \frac{4}{233.3}\right) = 87.4 \text{ (dB)}.$$

According to ДСН 3.3.6.037-99, in current case, the permissible sound pressure level at a frequency of 500 Hz is 49 Hz, hence the required noise reduction is $\Delta L = 38.4$ dB. So for current case some boundary layer should be located between workplaces and shop with machine-tool. Something like wall with sound absorption material may be suitable.

5.3 Instruction on labor protection when working at the computer

5.3.1 General labor protection requirements

When working at the computer in office building he employee must:

- Know hazardous and harmful production factors, know and be able to apply precautions and protective equipment (including personal) from hazardous and harmful production factors;
- Know the operating instructions for the office equipment;
- Know the points of connection of current collectors, switching devices, and be able to determine their good condition and be able to turn them off in emergency situations;
- Know the ways of evacuation of personnel and actions in case of emergencies;
- Know the location of fire extinguishing means and be able to use them;
- Observe the rules of personal hygiene;
- Not to allow the presence of foreign objects in your workplace that interfere with work.

Information on hazardous and harmful production factors arising from the operation of other equipment is contained in the instructions for their operation.

5.3.2 Labor protection requirements before starting work

Before starting work, each employee is obliged:

- To remove foreign objects from the workplace that are not required for the current work;
- Make sure by external examination that there is no mechanical damage to the electrical equipment, in case of damage and malfunctions of electrical equipment, do not use it and call technical personnel;
- Check the health and convenience of furniture arrangement;
- Check if the workplace is sufficiently lit. In case of insufficient illumination, it is necessary to organize local lighting, and locate the local lighting lamps so that when performing work, the light source does not blind the eyes of both the worker himself and those around him. Make sure that the work is safe, only after that you can start to work.

5.3.3 Labor protection requirements during operation

Each employee during work at the computer in the office building is obliged:

- To keep free passages to workplaces, not to clutter up the equipment with objects that reduce the heat transfer of office equipment and other equipment;
- Be attentive, not distracted or distract others;
- Not to allow pulling, twisting, bending and pinching the power supply cords of the equipment, do not allow any objects to be found on them and their contact with heated surfaces;
- During established breaks in work, perform the recommended exercises for the eyes, hands;
- Do not allow moisture to enter the surface of electrical equipment.

During work, it is not allowed to touch the moving parts of office equipment and other equipment and work with insufficient illumination of the workplace.

5.3.4 Labor protection requirements after work

After the end of work, it is necessary:

- To disconnect office equipment and other equipment from the mains, with the exception of equipment that is determined for round-the-clock work;
- Tidy up the workplace, paying special attention to its fire-fighting condition;
- Close windows;
- Turn off the lights;

5.3.5 Labor protection requirements at emergency situations

In the event of an emergency, an employee must:

- Immediately stop work, disconnect office equipment and other electrical equipment from the power supply, report an emergency and, if necessary, leave the hazardous area;
- To take part in the elimination of the emergency situation, if this does not pose a threat to the health or life of employees;
- In case of violations in the operation of office equipment, disconnect them from the power supply and call technical personnel;

– In the event of a temporary power outage, disconnect office equipment and other electrical equipment from the power grid; in the event of a fire, it is necessary to stop work, call the fire brigade, disconnect office equipment and other equipment from the mains, notify people nearby about the fire, take measures to evacuate people from the danger zone and take part in extinguishing the fire with the available primary fire extinguishing means, and if it is impossible to eliminate fire to leave the hazardous area, acting in accordance with fire safety instructions and evacuation plans.

Conclusion to the part 5

Analysis of harmful and dangerous production factors was made. It was found that the most significant negative harmful production factor is increased noise in the workplace. It can lead to serious health consequences. And it is difficult to maintain it at the required level at places like engineering office which is full of different electrical technique, air-conditioning systems and in some cases working premises located near shops, the sound from which can cause a lot of problems with noise regulation.

Measures to reduce the impact of harmful and dangerous production factors especially noise pollution were performed.

Finally instruction on labor protection when working at the computer in office building were proposed. There are general labor protection requirements, labor protection requirements before work, during work, after work and labor protection requirements at emergency situations.

6 ENVIRONMENTAL PROTECTION

6.1 Harm of aircraft to the environment

Air transport on a large scale has a negative impact on the environment. Nowadays, this problem is discussed quite often, because the environment near the airports is not considered favorable. The factors of the negative impact of aviation are emissions of harmful emissions into the atmosphere, noise and sound shocks, and electromagnetic radiation.

Although now they are developing and producing aircraft with a reduced content of such harmful factors, the ecology of modern aviation is still far from perfect.

Each major airport has its own water supply system. Such water is of poor quality, because it is not properly treated. Airports discharge oil products, heavy metals and many other harmful elements into wastewater, which pollutes local water.

As a result of the combustion of jet fuel, products are released into the air that have been stored in the atmosphere for many years. But the greatest amount of dangerous elements is released into the atmosphere during the warming up of the aircraft engine, takeoff and landing. At this time, impurities of carbon monoxide and hydrocarbon compounds are formed. And if air transport gets into an emergency, then it releases a lot of fuel into the air.

The plane emits huge amounts of nitrogen oxides when flying in the lower stratosphere. This factor is considered the most dangerous of those that affect the environment, because it oxidizes the ozonosphere, which protects the planet from radiation.

Despite the polluted air near airports, many people still live dangerously close to them. The national authorities are ignoring this problem, which has led to a large number of houses in the airport areas. This factor contradicts the protection of human health, because many hazardous substances are contained in the exhaust gases of aircraft, which cause various diseases in humans. Permanent stay near such areas should be limited, for which the authorities should pay special attention to this problem.

Small airports also harm the health of the people who live near them. Despite their smaller size compared to large airports, the negative impact from them is no less. The high concentration of substances emitted by such airports can cause various diseases of the heart, nervous system, blood vessels and other vital organs.

In addition to air pollution, airplanes create noise that is no less hazardous to health than harmful substances. Residents of areas near airports are constantly experiencing noise loads, which leads to hearing deviations and other dangerous diseases, including insomnia, nervousness, stress. There is a gradual habituation to the noise waves, but this is not normal. In humans, as a result of such a harmful neighborhood, the hearing threshold simply decreases, and often they do not notice it.

To solve these problems, it is necessary to actively apply standards in the design and construction of hazardous airport zones, to locate airports at a considerable distance from residential areas [6].

6.2 Calculation of the emissions

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 $\bar{R}$	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 taxing (regime of low gas)	0.07	7.0

Emission indexes of CO and NOx during ground operations with different aircraft engine types (kg of detrimental compound / kg of fuel) are given in Table 6.2.

Table 6.2 – Emission indexes of CO and NO_x during ground operations

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
AN-70	110	Europrop TP400	4	0.049	0.0546	0.0054

Weight rate of CO and NO_x emissions by aircraft represented in Table 6.3.

Table 6.3 – Weight rate of CO and NO_x emissions

Type of aircraft	Annual quantity of flight N	Relative thrust $\bar{R}$ of regimes 2, 3, 4 relatively	Weight rate of emissions W, kg/hour	
			CO	NO_2
AN-70	100	1	6.0	89
		0.85	7.5	61
		0.3	18.0	11

Calculations of annual emissions of CO and NO_x from aircraft engine are based on formulas:

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

$$\mathrm{M_{NO_x} = M_{NO_x\ GO} + M_{NO_x\ TLO}}, \tag{6.2}$$

where $\mathrm{M_{CO\ GO}}$, $\mathrm{M_{NO_x\ GO}}$ – masses of CO and NO_x, which are emitted during ground operations (start, idle running, from landing taxing – regime 1, 5);

$\mathrm{M_{CO\ TLO}}$, $\mathrm{M_{NO_x\ TLO}}$ – masses of CO and NO_x respectively, which are emitted during takeoff and landing operation (takeoff, climb to 1000 m, approach landing from a height of 1000 m – regimes 2, 3, 4).

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

$$\mathrm{M_{NO_x\ GO} = K_{NO_x} \cdot C_{SP\ LG} \cdot R_{LG} \cdot T_{LG}}, \tag{6.4}$$

where $\mathrm{K_{CO}}$, $\mathrm{K_{NO_x}}$ – emission indexes (kg of detrimental compound per kg of fuel) of *CO* and NO_x relatively during ground operations (Table 6.2);

$C_{SP\ LG}$ – specific consumption of fuel during regime of low gas, kg/N·hour (Table 6.2);

R_{LG} – engine thrust at low gas;

T_{LG} – operating time of engine at low gas for one takeoff and landing cycle (regimes 1, 5 at the Table 6.1), hours.

Engine thrust at low gas determined by formula:

$$R_{LG} = \overline{R} \cdot R_0, \tag{6.5}$$

where $\overline{R}$ – relative thrust;

R_0 – maximal trust of engine (Table 6.2).

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

$$M_{CO\ TLO} = W_{CO\ T} \cdot T_T + W_{CO\ C} \cdot T_C + W_{CO\ L} \cdot T_L, \tag{6.6}$$

$$M_{NO_x\ TLO} = W_{NO_x\ T} \cdot T_T + W_{NO_x\ C} \cdot T_C + W_{NO_x\ L} \cdot T_L, \tag{6.7}$$

where $W_{CO\ T}$, $W_{NO_x\ T}$ – weight rate of CO and NO_x emissions relatively during aircraft takeoff, kg/hour (Table 6.3);

$W_{CO\ C}$, $W_{NO_x\ C}$ – weight rate of CO and NO_x emissions relatively during climb to 1000 m;

$W_{CO\ L}$, $W_{NO_x\ L}$ – weight rate of CO and NO_x emissions relatively during approach landing from a height of 1000 m;

T_T, T_C, T_L – operating time of engine during takeoff, climb to 1000 m and descent from 1000 m relatively (Table 6.1).

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

$$M_{CO\ AZ} = M_{CO} \cdot N \cdot n \text{ (kg/year)}, \tag{6.8}$$

$$M_{NO_x\,AZ} = M_{NO_x} \cdot N \cdot n \text{ (kg/year)}, \qquad (6.9)$$

where N – annual quantity of takeoff-landing of the aircraft at the airport;

n – quantity of engines of the aircraft.

So for aircraft AN-70 engine thrust at low gas will be:

$$R_{LG} = 0.07 \cdot 110000 = 7700 \text{ (N)}.$$

Masses of CO and NO_x which are emitted during ground operations:

$$M_{CO\,GO} = 0.0546 \cdot 0.049 \cdot 7700 \cdot 0.37 = 7.62 \text{ (kg)},$$

$$M_{NO_x\,GO} = 0.0054 \cdot 0.049 \cdot 7700 \cdot 0.37 = 1.51 \text{ (kg)}.$$

Masses of CO and NO_x emissions relatively during takeoff and landing operations:

$$M_{CO\,TLO} = 6 \cdot 0.017 + 7.5 \cdot 0.037 + 18 \cdot 0.067 = 1.59 \text{ (kg)},$$

$$M_{NO_x\,TLO} = 89 \cdot 0.017 + 61 \cdot 0.037 + 11 \cdot 0.067 = 4.15 \text{ (kg)}.$$

Determine annual emissions of CO and NO_x from Europrop TP400 engine:

$$M_{CO} = 7.62 + 1.59 = 9.21 \text{ (kg)},$$

$$M_{NO_x} = 1.51 + 4.15 = 5.66 \text{ (kg)}.$$

Emissions of CO and NO_x of aircraft at the zone of airport per year:

$$M_{CO\,AZ} = 9.21 \cdot 100 \cdot 4 = 3684 \text{ (kg/year)},$$

$$M_{NO_x\,AZ} = 5.66 \cdot 100 \cdot 4 = 2264 \text{ (kg/year)}.$$

The ICAO standard according to control emission parameters for modern engines has standard value for relations between masses of CO and NO_x and maximal thrust of engine.

For engine Europrop TP400 these relations are next:

$$\frac{M_{CO}}{R_0} = \frac{9210}{110} = 83.72\ (g/kN),$$

$$\frac{M_{NOx}}{R_0} = \frac{5660}{110} = 51.46\ (g/kN).$$

According to ICAO standard these relation should be next:

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

So after calculations values M_{CO}/R_0 and M_{NOx}/R_0 are in the acceptable limits per control emission parameters for modern engines.

Conclusion to the part 6

Calculations show that engine emissions during regime of start, idle running before takeoff and from landing taxiing (regimes of low gas) are equal to 7.62 kg for CO and 1.51 kg for NO_x, and during takeoff, climb and approach landing from the height of 1000 m regimes emissions of CO are equal to 1.59 kg and emissions of NO_x are equal to 4.15 kg. It can be concluded that maximum quantity of CO emissions are take place at regimes of low gas and maximum quantity of NO_x pollute environment during takeoff, climb and approach landing from the height of 1000 m regimes.

To decrease emission of the engines at regimes of low gas, where relative thrust of engines is small, method of some engines turning off can be used. So using this way of emissions decreasing working engines will develop higher thrust but summary consumption of fuel and hence level of emissions of CO and NO_x will be lower.

GENERAL CONCLUSION

The problem of loading vehicles in aircraft and ways to overcome that has been introduced. Design and construction of one of the advanced cargo ramps for loading and unloading heavy cargo aircraft were described. Advantages and disadvantages of it were determined. Requirements for modular cargo ramp were determined, main of them are simple design, low weight, low in cost and easy to operate and manufacture. As a result the aim and objectives of the work have been formulated.

To achieve the aim and to solve the problem of the facilitating the process of cargo aircraft loading by the new module ramp the following methods and procedures have been selected:

1. Software CATIA V5 for 3D modeling of the proposed concept.
2. FEM stress-strain analysis by ANSYS software application.
3. Standard components of the aircraft preliminary design.

The selected methods and procedures allow solving the main tasks of the thesis. The use of several specific software allows obtaining the most accurate final parameters of the desired modular ramp and optimizing its design where necessary. As a result, the preliminary design procedure made it possible to obtain required object for application and investigation of the modular ramp.

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 were performed. Also engines which meet the requirements for the designed aircraft was selected. The aircraft layout reflects main features of contemporary transport aircraft. The center mass position characteristics was determined. It was showed the main calculations of an aircraft. Also the mass position of the main parts of the aircraft and main equipment and furnishing by its distance from the main aerodynamic chord were checked. After designing of the wing and the fuselage the calculations of the center of gravity determination of the equipped aircraft was made. The result was data and characteristics for preliminary design of aircraft as object for module ramp for aircraft loading application.

Creation of 3D models in CATIA, analysis in ANSYS Workbench, determination of required characteristics, optimization and modification of structure and final specification of modular cargo ramp units for aircraft loading was performed.

To meet requirements of the Environmental protection and Labor protection the procedures developed by the Department of Ecology and Department of Civil and Industrial Safety were applied. Analysis of harmful and dangerous production factors was made. It was concluded that the most significant negative harmful production factor is increased noise in the workplace. It can lead to serious health consequences. And it is difficult to maintain it at the required level at places like engineering office which is full of different electrical technique, air-conditioning systems and in some cases working premises located near shops, the sound from which can cause a lot of problems with noise regulation.
Measures to reduce the impact of harmful and dangerous production factors especially noise pollution were performed. Finally instruction on labor protection when working at the computer in office building were proposed. For Environmental protection some aspects of the influence of aircraft on environment and emissions calculation were performed. Also some recommendation for emissions decreasing was proposed.

The result was modular cargo ramp that can operate with light, middle and large cargo aircrafts. Vehicle with weight up to 10 tons per one axle can be loaded and unloaded using designed cargo ramp. Designed equipment has possibility to be assembled in various configurations on height up to 81 cm. Height of support can be increased by using more long upper part of support. Designed cargo ramp corresponds to all requirements that was described in part 1. It is easy in construction and as result easy to operate and manufacture, so low in cost. Weight of each part of the equipment gives possibility to operate with it by one-two person.

The main advantage of the modular cargo ramp is its simple and universal design which make it possible to modify it and use it in many scenarios.

The main disadvantage of the designed cargo equipment is not the most impressive performance characteristics and it cannot compete with more advanced and highly specialized ramps and overpasses.

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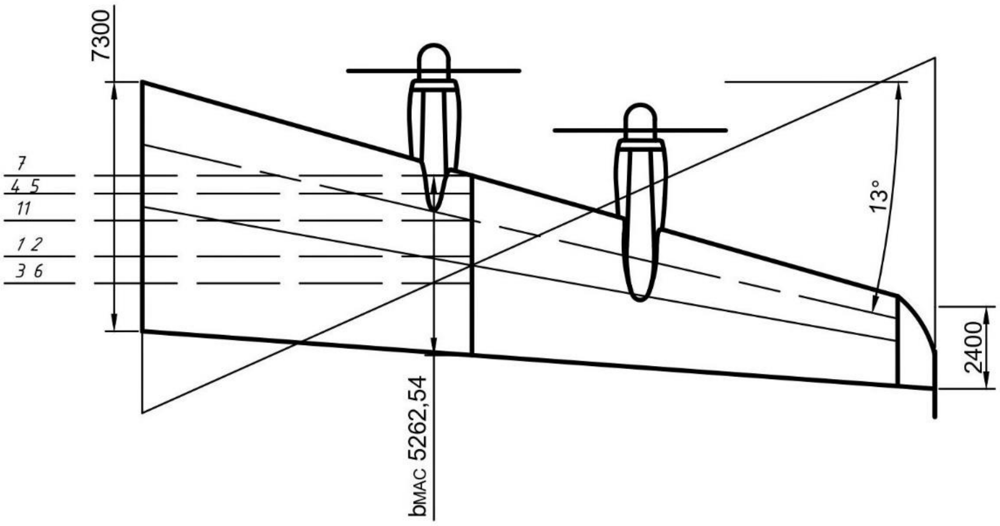
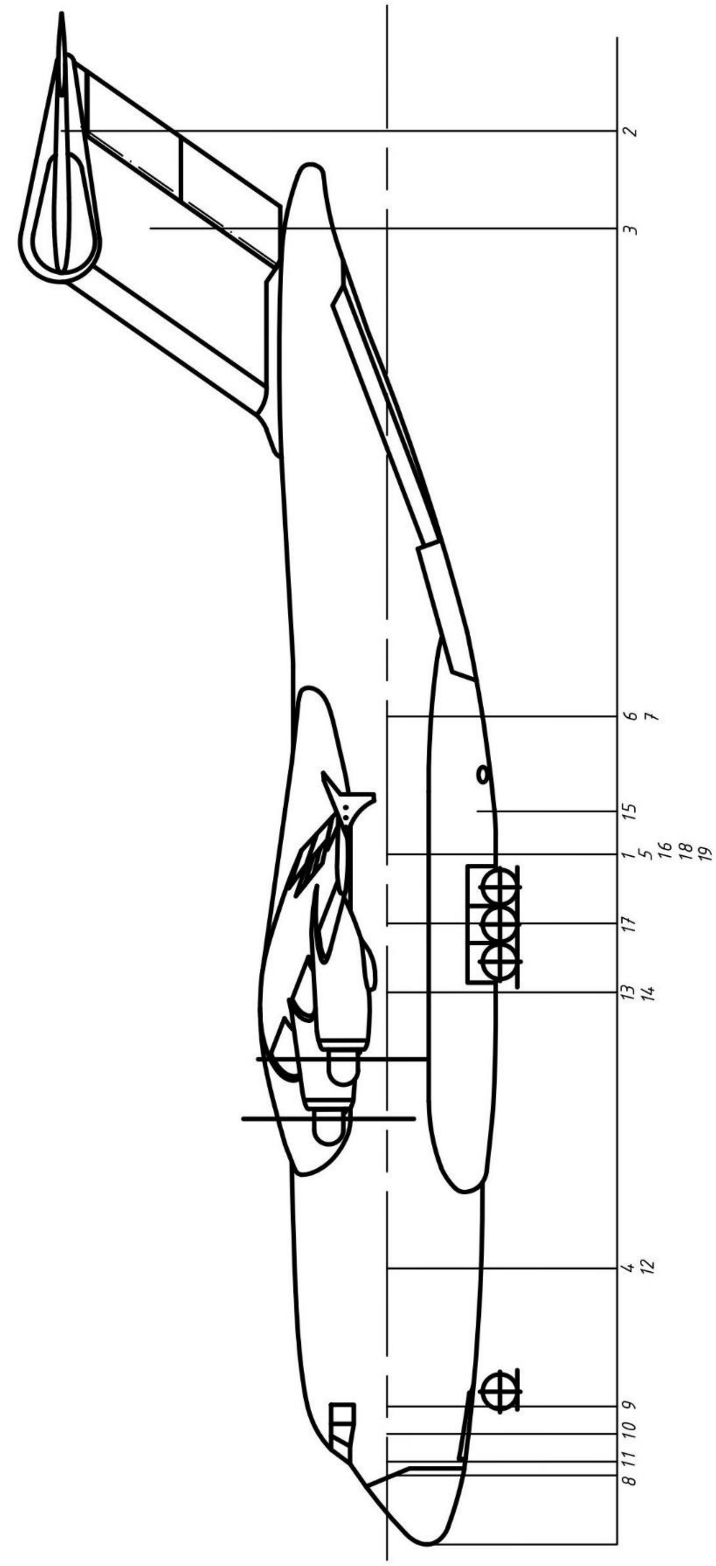
Appendix A

M 1:200



Appendix B. Coordinates of C.G. of equipped wing

M 1:200



Appendix C. Coordinates of C.G. of equipped fuselage