МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Кафедра конструкції літальних апаратів

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
д-р техн. наук, проф.
_____________ С. Р. Ігнатович
«_____» ___________ 2020 р.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)
ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ
"БАКАЛАВР"

Тема: «Аванпроект середньомагістрального літака вантажопідйомністю до 76 тонн»

Виконав: ___________ **Захірі Амір Хоссеін**

Керівник: канд.техн.наук, доцент ___________ **Т.П. Маслак**

Нормоконтролер: канд.техн.наук, доцент ___________ **С.В. Хижняк**

Київ 2020

MINISRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY

Department of Aircraft Design				NAU 20 04Z 00 00 00 48 EN			
Performed by	Zahiri Amir hossein			Special part	Letter	Sheet	Sheets
Supervisor	Maslak T.P.						
					402 AF 138		
Stand.contr.	Khizhnyak S.V.						
Head of dep.	Ignatovych S.R.						

Department of Aircraft Design

AGREED
Head of the Department
Professor, Dr. of Sc.
_________S.R. Ignatovych
«___» _______ 2020

DIPLOMA WORK

(EXPLANATORY NOTE)
OF ACADEMIC DEGREE

«BACHELOR»

Theme: «Preliminary design of a middle range aircraft with cargo capacity up to 76 tons»

Performed by: __________ **Zahiri Amir Hossein**

Supervisor: PhD, associate professor __________ **T.P. Maslak**

Standard controller: PhD, associate professor __________ **S.V. Khizhnyak**

Kyiv 2020
NATIONAL AVIATION UNIVERSITY

Aerospace Faculty

Department of Aircraft Design

Academic Degree «Bachelor»

Speciality: 134 "Aviation and Rocket-Space Engineering"

APPROVED
Head of the Department
Professor, Dr. of Sc.
_________S.R. Ignatovych
«___» _______ 2020

TASK

for bachelor diploma work

ZAHIRI AMIR HOSSEIN

1. Theme: **«Preliminary design of mid-range cargo aircraft with payload 76 tons** »

confirmed by Rector's order from 05.06. 2020 year № 801/ст

2. Period of work execution: from 25.05. 2020 year to 21.06.2020 year.

3. Work initial data: cruise speed 830km/h, flight range 4480km, operating altitude 7,9 km, payload up to 76 tons.

4. Explanation note argument (list of topics to be developed): choice and substantiations of the airplane scheme, choice of initial data; engine selection, aircraft layout, center of gravity position calculation, pallet construction.

5. List of the graphical materials: general view of the airplane (A1×1); layout of the airplane (A1×1); assembly drawing of the pallet (A1×1); assembly drawing of the attachment mechanism (A1×1).

Graphical materials are performed in AutoCAD, Solid Works, CATIA.

6. Calendar Plan

Task	Execution period	Signature
Task receiving, processing of statistical data	25.05.2020–28.05.2020	

Aircraft take-off mass determination	29.05.2020–30.05.2020	
Aircraft layout	1.06.2020–7.06.2020	
Aircraft centering determination	8.06.2020–10.06.2020	
Graphical design of the parts	12.06.2020–13.06.2020	
Preliminary defence	14.06.2020–15.06.2020	
Completion of the explanation note	16.06.2020–21.06.2020	

7. Task issuance date: 25.05.2020 year

Supervisor of diploma work ___________ T.P. Maslak

Task for execution is given for ___________ Zahiri Amir Hossein

ABSTRACT

Explanatory note to the diploma work «Preliminary design of a middle range aircraft with cargo capacity up to 76 tons» contains:

sheets, figures, tables, references and drawings

Object of the design is development of cargo aircraft with the possibility to transport cargo of 76 tons.

Aim of the diploma work is the preliminary design of the aircraft and its design characteristic estimation.

The method of design is analysis of the prototypes and selections of the most advanced technical decisions, center of gravity calculations.

The diploma work contains drawings of the mid-range aircraft with a carrying capacity of 76 tons, calculations and drawings of the aircraft layout and pallet construction.

AIRCRAFT, PRELIMININARY DESIGN, LAYOUT, CENTER OF GRAVITY POSITION, PALLET CONSTRUCTION

CONTENT

GENERAL CONCLUSIONS

According to information that achieved during work on diploma project and comparison of results that has been obtained based on calculations following results have been determined:

- at the first stage we compared different specifications of prototypes and chose Boeing C-17 which had most similar characteristics to our given data;
- processed preliminary design of middle range cargo aircraft with payload capacity of 76 ton, taking into account geometrical characteristic of airplane and safety requirements to calculate the basis of a successful and cost-effective plan for desire airlifter;
- calculated basic geometric parameters of appropriate landing gear for designed aircraft and selected proper type of tire capable of withstanding calculated transmitted loads on nose and main landing gear;
- introduced cargo compartment's facilities for loading-unloading process as well as keeping cargo in safest manner during flight.
- center of gravity position of the equipment's projected on aircraft based on their mass, moment and coordinates on mean aerodynamic chord , which has range between 18 to 23 %;
- selection and installation of turbo fan engine PW 2000 series of high-bypass turbofan aeroengines with a thrust range from 160 to 190 kN which has outstanding cruising speed and a good thrust to weight ration.
- conceptual pallet design, which first chose, material and dimensions of required pallet, then calculated external and internal forces that apply to pallet when it places on 4 supports on cargo hold floor, and then I compared with allowable stress of materials that they constructed from and finally checked the strength of pallet under overload condition.

INTRODUCTION

Air cargo known as any property that carried or to be carried with an aircraft to another location. Air cargo taransportation systems play an importante role in aviation industry, it is occupation field in the logistics and warehousing sector of the airline industry in which they are stored and shipped across the country and around the world via commercial and private services. The transportation of goods from place to place is becoming more and more common in today's global marketplace.

A cargo aircraft is desigened to carry cargo instead of passengers, these cargo aircrafts has fitures which separate them from passenger aircraft. To mention few fetures, first is their wide and tall fuselage cross section in which cargo will place, next, a high-wing construction to allow the cargo area to sit near the ground, many wheels to allow it land at unprepared locartions in condtions such as emergency supplement at battlefield and a high-mounted tail unit to allow easy placement of cargo during loading and unloading in the airplane.

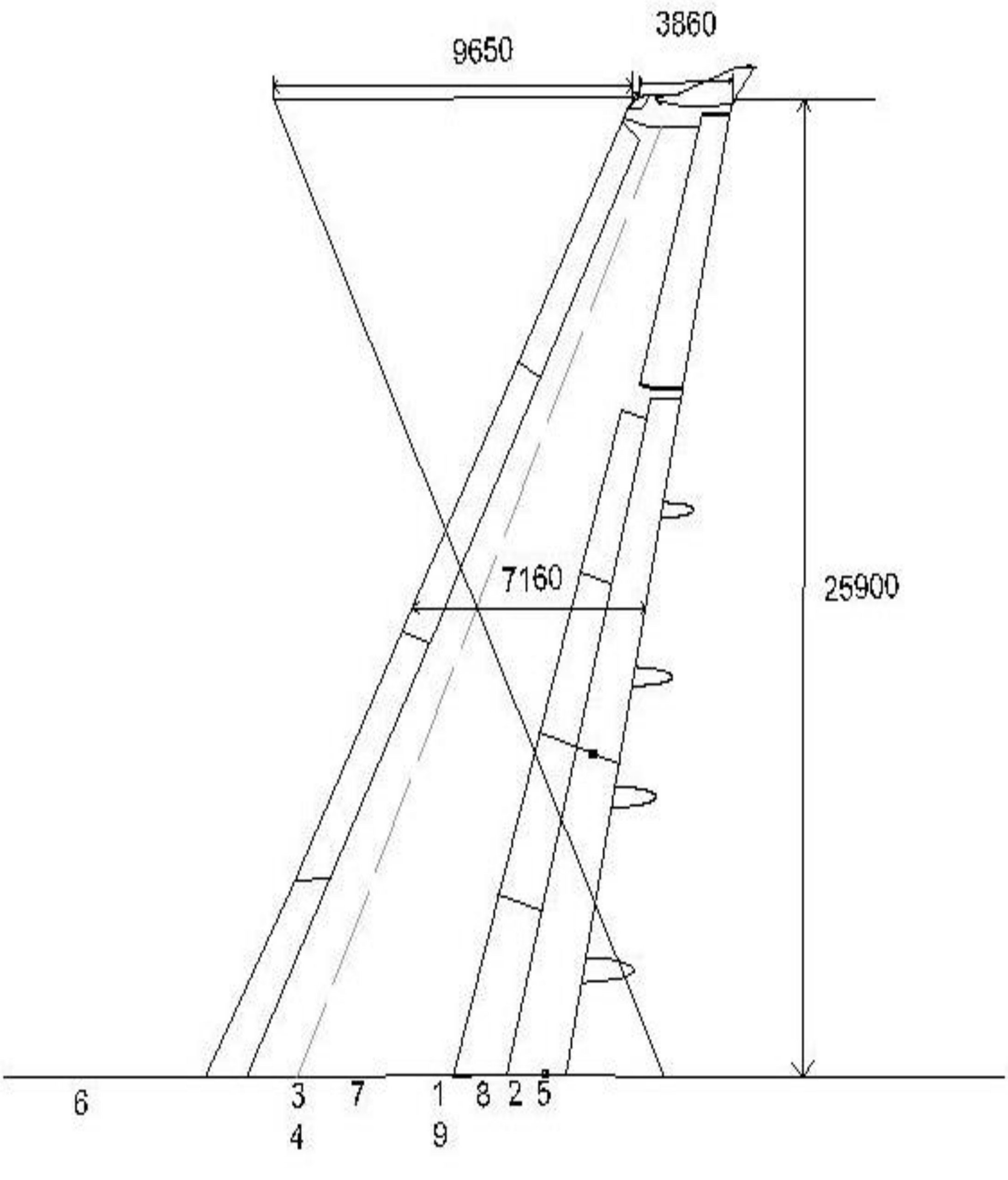
The purpose of the work is Preliminary design of middle - range cargo aircraft with payload 76 tons. The main prototype for this work are Boeing C-17 Globemaster III, Antonov An-124 Ruslan and Airbus A400M Atlas

List of diploma work

Format	№	Designation	Name	Quantity	Notes
			<u>General documentation</u>		
A4	1	NAU 20 04Z 00 00 00 48 TW	Task of diploma work	1	
			<u>Graphic documentation</u>		
			Middle range cargo aircraft		
A1	2	NAU 20 04Z 00 00 00 48 GV	General view	1	
A1	3	NAU 20 04Z 00 00 00 48 AL	Aircraft layout	1	
A4	4	NAU 20 04Z 00 00 00 48 EN	Explanatory note		
			<u>Documentation for assembly units</u>		
A1, A2	5	NAU 20 04Z 00 00 00 48 AD	Pallet's assembly drawing	1	
A4	6	NAU 20 04Z 00 00 00 48 AD	Power drive unit assembly drawing	1	

Department of aircraft design				NAU 20 04Z 00 00 00 48 EN			
Done by	Zahiri.A.H			List of diploma work	list	sheet	sheets
Supervisor	Maslak T.P.						
					402 AF 134		
N. contr.	Khizhnyak S.V.						
Head. of d.	Ignatovich S.R.						

Appendix B



3860
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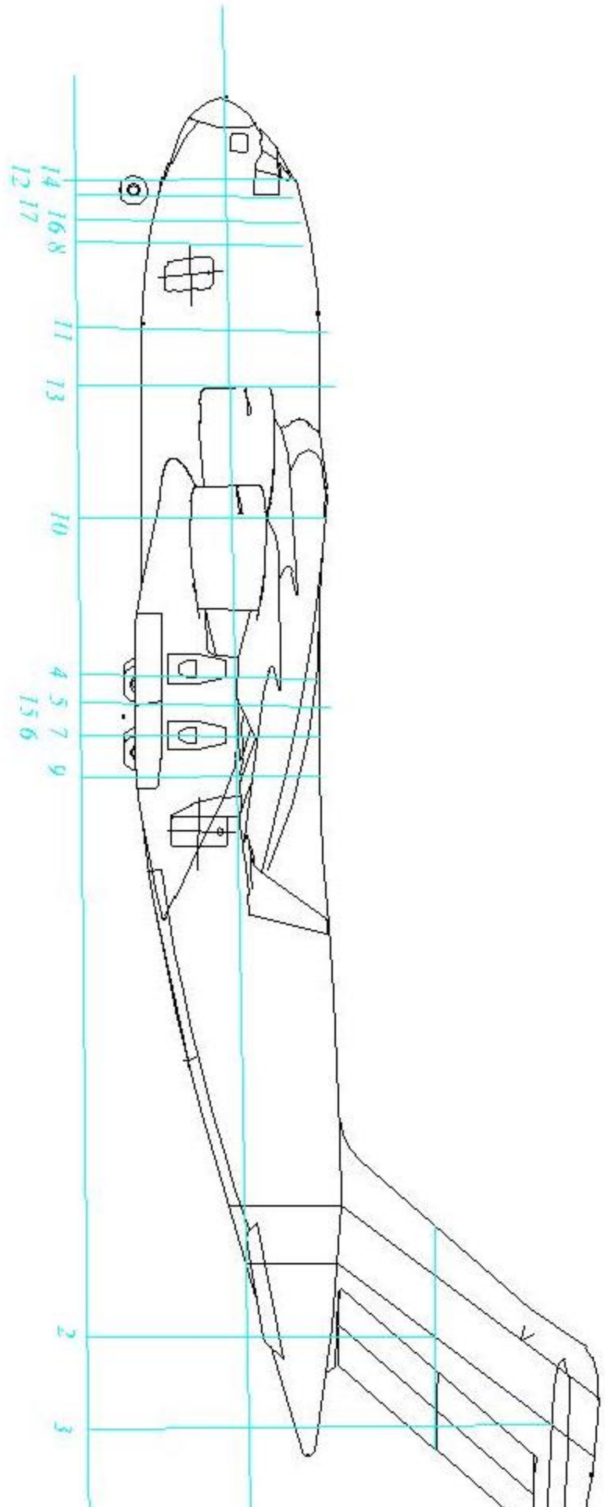
Appendix C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Appendix A

П Р О Е К Т
С А М О Л Е Т А С Т Р Д Д
Н А У, кафедра К Л А

ПРОЕКТ дипломный Расчет выполнен 04.03.2020
Исполнитель Довбня Анастасия Викторовна Руководитель Маслак Т.П.

ИСХОДНЫЕ ДАННЫЕ И ВЫБРАННЫЕ ПАРАМЕТРЫ

Количество пассажиров
0
Количество членов экипажа
2
Количество бортпроводников или сопровождающих
1
Масса снаряжения и служебного груза
1451.10 кг
Масса коммерческой нагрузки 77500.00 кг

Крейсерская скорость полета
830.км/ч
Число "М" полета при крейсерской скорости
0.7458
Расчетная высота начала реализации полетов с крейсерской

экономической скоростью 7.90
км
Дальность полета с максимальной коммерческой нагрузкой
4480.км
Длина летной полосы аэродрома базирования
2.20 км

Количество двигателей
4
Оценка по статистике тяговооруженности в н/кг
2.7700
Степень повышения давления
30.80
Принятая степень двухконтурности двигателя
6.00
Оптимальная степень двухконтурности двигателя
6.00
Относительная масса топлива по статистике
0.2200

Удлинение крыла
7.67
Сужение крыла
2.50
Средняя относительная толщина крыла
0.120
Стреловидность крыла по 0.25 хорд 22.0
град.
Степень механизированности крыла
1.160
Относительная площадь прикорневых наплывов
0.000
Профиль крыла - Суперкритический
Шайбы УИТКОМБА - не применяются
Спойлеры - установлены

Диаметр фюзеляжа 6.86
м
Удлинение фюзеляжа 7.72
Стреловидность горизонтального оперения
30.0град
Стреловидность вертикального оперения
35.0град

Р Е З У Л Ь Т А Т Ы   Р А С Ч Е Т А
Н А У,   КАФЕДРА   "К Л А"

Значение оптимального коэффициента подъемной силы в расчетной точке крейсерского режима полета   Cy   0.41275

Значение коэффициента   Cx.инд.   0.00928

ОПРЕДЕЛЕНИЕ КОЭФФИЦИЕНТА Dм = Мкрит - Мкрейс

Число Маха крейсерское	Мкрейс	0.74576
Число Маха волнового кризиса	Мкрит	0.76340
Вычисленное значение	Dм	0.01763

Значения удельных нагрузок на крыло в кПА(по полной площади):

при взлете	6.888
в середине крейсерского участка	5.830
в начале крейсерского участка	6.719

Значение коэффициента сопротивления фюзеляжа и гондол
0.01253

Значение коэфф. профиль. сопротивления крыла и оперения
0.00932

Значение коэффициента сопротивления самолета:

в начале крейсерского режима
0.03397

в середине крейсерского режима
0.03256

Среднее значение Cy при условном полете по потолкам
0.41275

Среднее крейсерское качество самолета
12.67845

Значение коэффициента Cy.пос.
1.764

Значение коэффициента (при скорости сваливания) Cy.пос.макс.
2.646

Значение коэффициента (при скорости сваливания)Cy.взл.макс.
2.156

Значение коэффициента Cy.отр.
1.574

Тяговооруженность в начале крейсерского режима
0.715

Стартовая тяговооруженность по условиям крейс. режима Ro.кр.
2.223

Стартовая тяговооруж. по условиям безопасного взлета Ro.взл.
2.991

Расчетная тяговооруженность самолета	Ro	3.111
Отношение Dr = Ro.кр / Ro.взл	Dr	0.743

УДЕЛЬНЫЕ РАСХОДЫ ТОПЛИВА (в кг/кН*ч):

взлетный
34.7246
крейсерский (характеристика двигателя)
60.4164
средний крейсерский при заданной дальности полета
66.2778

ОТНОСИТЕЛЬНЫЕ МАССЫ ТОПЛИВА:

аэронавигационный запас	0.04705
расходуемая масса топлива	0.26639

ЗНАЧЕНИЯ ОТНОСИТЕЛЬНЫХ МАСС ОСНОВНЫХ ГРУПП:

крыла	0.07683
горизонтального оперения	0.00917
вертикального оперения	0.01041
шасси	0.04073
силовой установки	0.10368
фюзеляжа	0.08195
оборудования и управления	0.10262
дополнительного оснащения	0.00231
служебной нагрузки	0.00476
топлива при Lрасч.	0.31344
коммерческой нагрузки	0.25418

Взлетная масса самолета "M.o" = 304901. кГ.
Потребная взлетная тяга одного двигателя 237.14 kH

Относительная масса высотного оборудования и противообледенительной системы самолета
0.0106
Относительная масса пассажирского оборудования
0.0001
Относительная масса декоративной обшивки и ТЗИ
0.0043
Относительная масса бытового (или грузового) оборудования
0.0433
Относительная масса управления
0.0031
Относительная масса гидросистем
0.0099
Относительная масса электрооборудования
0.0118
Относительная масса локационного оборудования
0.0039
Относительная масса навигационного оборудования
0.0058
Относительная масса радиосвязного оборудования
0.0029

Относительная масса приборного оборудования
0.0068
Относительная масса топливной системы (входит в массу "СУ")
0.0102
Дополнительное оснащение:
Относительная масса контейнерного оборудования
0.0000
Относительная масса нетипичного оборудования
0.0023
[встроенные системы диагностики и контроля параметров, дополнительное оснащение салонов и др.]

ХАРАКТЕРИСТИКИ ВЗЛЕТНОЙ ДИСТАНЦИИ

Скорость отрыва самолета 301.10 км/ч
Ускорение при разбеге 2.44 м/с*с
Длина разбега самолета 1430. м.
Дистанция набора безопасной высоты 472. м.
Взлетная дистанция 1903. м.

ХАРАКТЕРИСТИКИ ВЗЛЕТНОЙ ДИСТАНЦИИ
ПРОДОЛЖЕННОГО ВЗЛЕТА

Скорость принятия решения 270.99 км/ч
Среднее ускорение при продолженном взлете на мокрой ВПП 1.13 м/с*с
Длина разбега при продолженном взлете на мокрой ВПП 1716.80 м
Взлетная дистанция продолженного взлета 2189.05 м
Потребная длина летной полосы по условиям прерванного взлета 2267.27 м

ХАРАКТЕРИСТИКИ ПОСАДОЧНОЙ ДИСТАНЦИИ

Максимальная посадочная масса самолета 233789. кг
Время снижения с высоты эшелона до высоты полета по кругу 14.6 мин
Дистанция снижения 33.73 км
Скорость захода на посадку 267.80 км/ч
Средняя вертикальная скорость снижения 2.13 м/с
Дистанция воздушного участка 524. м

Посадочная скорость 252.80 км/ч
Длина пробега 819 м
Посадочная дистанция 1343 м
Потребная длина летной полосы (ВПП + КПБ) для основного аэродрома 2243 м
Потребная длина летной полосы для запасного аэродрома 1907 м

ПОКАЗАТЕЛИ ЭФФЕКТИВНОСТИ САМОЛЕТА

Отношение массы снаряженного самолета к массе коммерческой нагрузки 1.6923
Масса пустого снаряженного с-та приход. на 1 пассажира 0.00 кг/пас
Относительная производительность по полной нагрузке 471.12 км/ч
Производительность с-та при макс.коммерч. нагрузке 60938.0 кг*км/ч
Средний часовой расход топлива 14255.635 кг/ч
Средний километровый расход топлива 18.13 кг/км
Средний расход топлива на тоннокилометр 233.937г/(т*км)
Средний расход топлива на пассажирокилометр 0.0000г/(пас.*км)
Ориентировочная оценка приведен. затрат на тоннокилометр 0.3301 $/(т*км)

1 PRELIMINARY DESIGN OF THE AIRCRAFT

1.1 Choise of the projected data of designing aircraft

There are three phases of aircraft design; conceptual, preliminary, and detail phases. Among them, the conceptual design phase is characterized by the initial definitions that come from requirements established by market needs.

After completing the conceptual design, the next phase is preliminary design. Engineers may use the existing designs to conduct wind tunnel testing and fluid dynamic calculations. Furthermore, structural and control analyses are performed during this stage.

Last but not least is the detail design phase. During this phase, engineers must use the existing designs to fabricate the actual aircraft. It specifically determines the design, location and quantity of elements such as ribs, spars, sections and more.

The selecting of the optimal design parameters of the aircraft is the multidimensional optimization task. In its configuration mean the whole complex flight-technical, weight, geometrical, aerodynamic and economic characteristics.

Our task in this stage of diploma work is analysis of various prototypes according to our initial data. After we inputted our approximate data that we gatherd from different resources into computer program, we recived more accurate initial data to begine our project. Our task was to choose a transport aircraft with cargo capacity of 76 tons to transport given payload on maximum range of 4480 km.

On the table 1.1 and 1.2, we have operational–technical and geometric parameters of three different transport aircraft which have similar characteristic and parameters to our desierd aircraft. Prototypes that choosed for comparison are as following:

Table 1.1 - Operational- technical data of plane prototype

Name and dimensions	Boeing C-17 Globemaster III	Antonov An-124 Ruslan	Airbus A400M Atlas
Max payload, kg	77 500	150 000	37 000
Crew, numbers	2	6	3
Flight Range with MTOW, km	4480	3700	3300
Cruise speed, km/h	830	865	781
Cruise altitude, km	7,9	10	9
Number and type of engines	4 (Pratt &Whitney F117-PW-100)	4 (Progress D-18T)	4 (Europrop TP400-D6)
Take off run at MTOW, m	2,499	3000	3500
Landing distance, m	1067	2800	770
Landing speed, km/h	244	-	-
Field length for take off, km	1,2	2,8	0,77
Thrust (each engine), kN	180	229	177
Degree bypass ratio	5,9	5,6	5,4

Table 1.2 - Geometrical parameters of prototypes

Name and dimensions	Boeing C-17 Globemaster III	Antonov An-124 Ruslan	Airbus A400M Atlas
Length of the fuselage, m	53	69.1	45.1
Wingspan, m	52	73.3	42.4
Wing area, m^2	353	628	225.1
Aspect ratio	7,67	8.6	8.5
Sweepback angle, degree	22	25	15
Height at tail, m	16.79	21.08	14.70
Fuselage diameter, m	6.86	10	5.64
Wing tapper ratio, m	0,25	0,25	0,25
Mean geometric chord, m	7,7	-	-

McDonnell Douglas/Boeing C-17 Globemaster III shown on figure 1.1 is a large military transport aircraft, developed for the United States Air Force. The C-17 is a strategic transport aircraft, able to airlift cargo close to a battle area. It is powered by four Pratt & Whitney F117-PW-100 turbofan engines, which produce 180 KN of thrust. Maximum payload of the C-17 is 77.500kg, and its maximum take off weight is 265,000kg. With a payload of 73,000kg and an initial cruise altitude of 8,500m the C-17 has an unrefueled range of about 4,400km. The main advantage of C-17 is that it designed to operate from runways as short as 1,100m and as narrow as 27m.

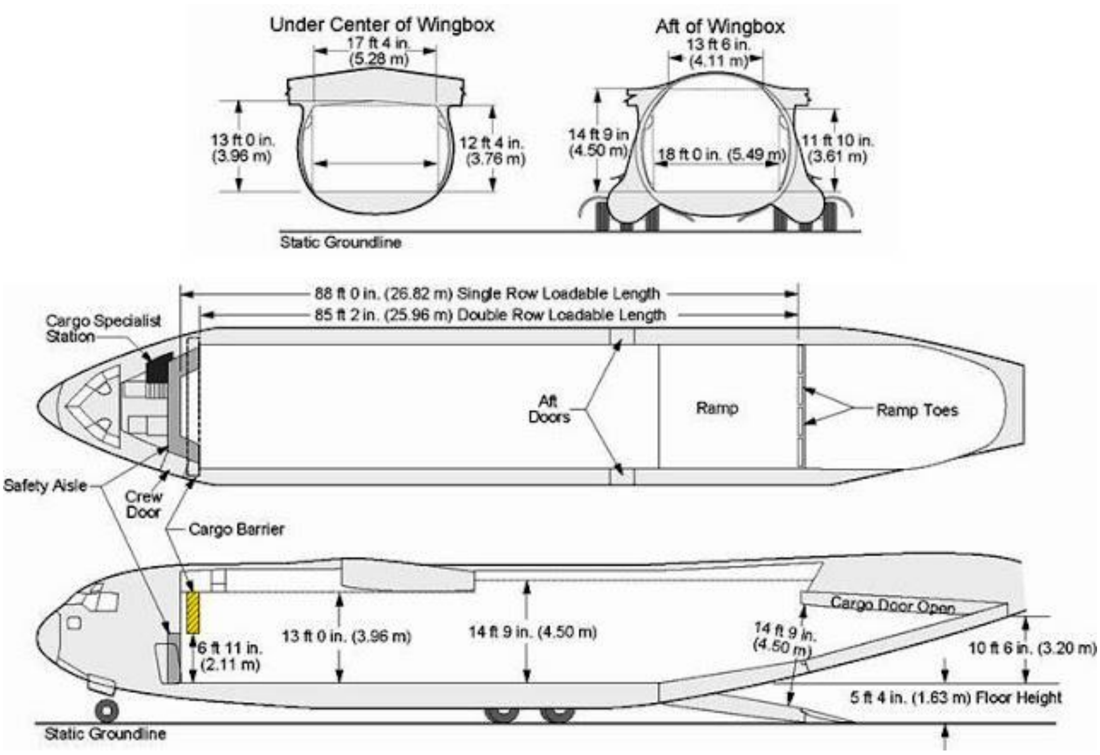

Figure 1.1 – General view and cabin layout of C-17

Figure 1.2 – Cargo compartment of C-17

The Antonov An-124 (Ruslan) is a strategic airlift quadjet, designed by Antonov Company and remains the largest military transport aircraft in current service. The lead designer of the An-124 (and the An-225) was Viktor Tolmachev. It has a double fuselage structure (figure 1.3 and 1.4) to allow rear cargo door (on the lower fuselage) to open in flight without affecting structural integrity. The An-124 uses a conventional empennage; and also we can mention oleo-strut suspension for its 24 wheels landing geras. The cargo compartment of An-124 is 36×6.4×4.4 m and its capacity is 88 passengers in upper aft fuselage, or the hold can take an additional 350 pax on a palletised seating system / 150,000kg. With a range of 3,700km with max payload.

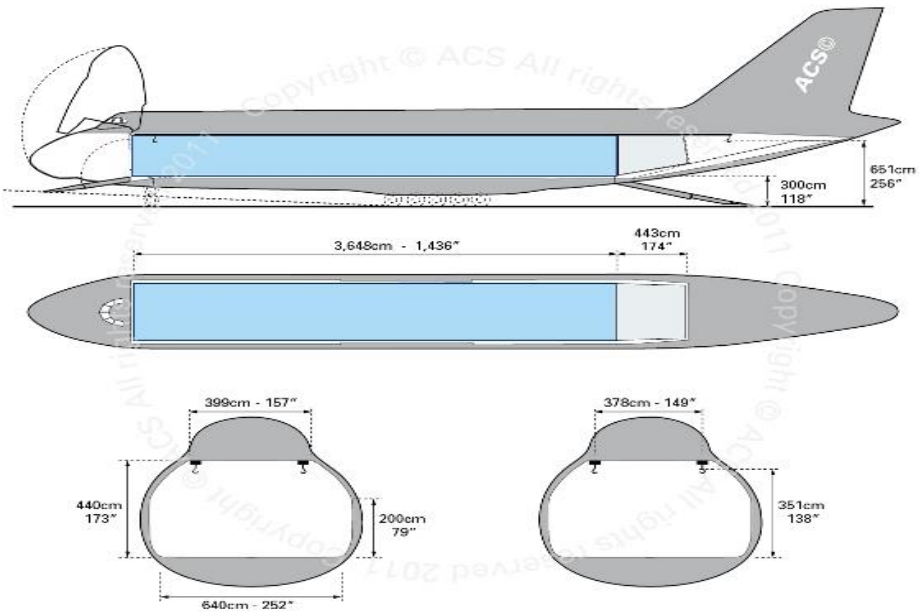

Figure 1.3 – General view and cabin layout of An-128

Figure 1.4 – Cargo compartment of An-128

Airbus A400M Atlas: is a European,four-engine turboprop military transport aircraft(figure1.5 and 1.6), designed by Airbus Military department . The cargo compartment is 17,71m long excluding ramp, 4,00m wide and 3.85 m high (or 4.00 m aft of the wing). The maximum payload of 37 tonnes can be carried over 3,700km. The A400M operates in many configurations including cargo transport, troop transport, and medical evacuation. It is intended for use on short, soft landing strips and for long-range, cargo transport flights. The wings are primarily carbon fibre reinforced plasticIt and aircraft is powered by four Europrop TP400-D6 engines rated at 8,250kw (11,000 hp) each.

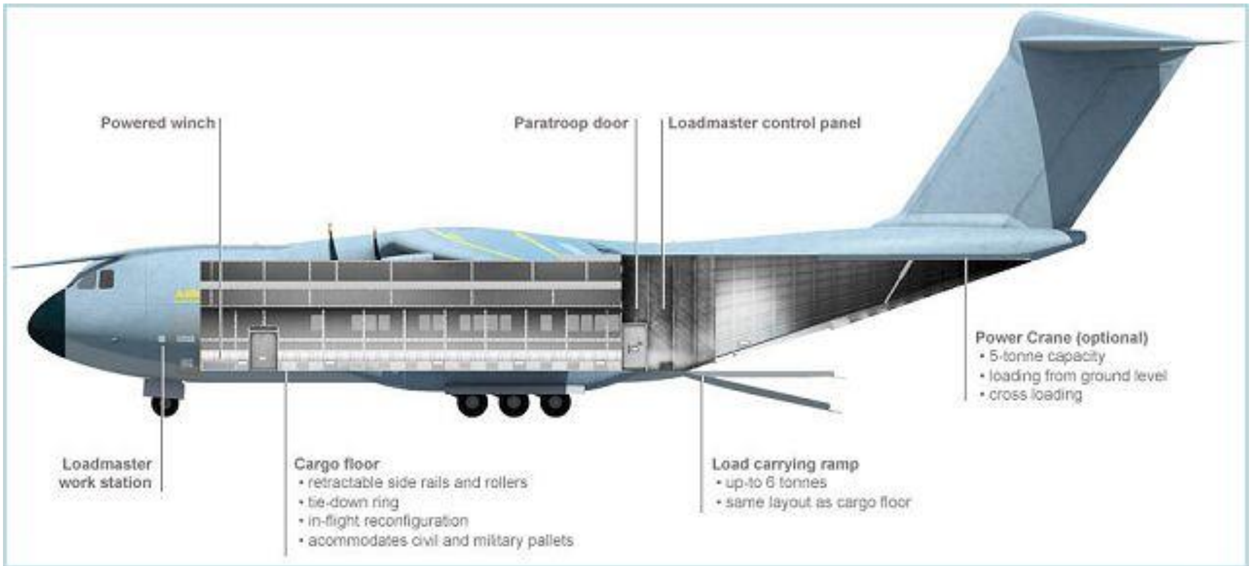

Figure 1.5 – General view of A400M Atlas

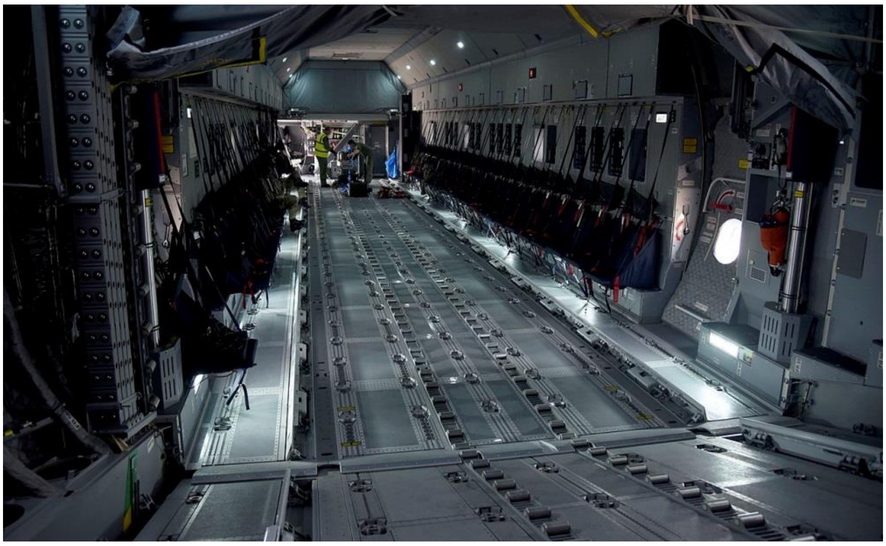

Figure 1.6 – Cargo compartment of A400M Atlas

The first step to develop this project is to choose the aircraft that is going to be analysed as prototype. The first general idea was to choose an interesting aircraft that allowed a deep structural study throughout research and general aeronautical knowledge.

After comparing technical data of given prototypes based on given task, in my point of view the most optimal choise for this task is Boeing C-17 Globemaster III. The reasons for chosing this aircraft is: firstly we can effiecintly fit our payload inside cargo compartment, as for An-124 we would face a great deal of emty space.

An-124 is enormous aircraft and its functioning with out usage of best economical space in cargo hold will costs additional money for fuel.on the other hand A400M has maximum payload capacity of 37tonnes and it can not operate with our require payload.

Next, is range of aircraft that only C-17 can cover this distance perfectly with consideration of payload capacity. Finally to fit our cargo insid cargo compartment we calculated size of our pallet and container in ratio of cargo hold, the result for most economical way was C-17 cargo compartment.

The aircraft considerd to designe in this project is large military transport aircraft.It has high-wing, four engines and Tshape tail unit, it is able to carry large cargo, equipment and supplies directly to small airfelds in harsh terrain. It has maximum payload up to 76000kg, establishing the maximum altitude to 7,9m settling for a range of about 4480m.

1.2 Brief description of the main parts of the aircraft

Basically, the aircraft that is going to be studied has conventional specification. However, its scale is one of the biggest in the world. Both the wingspan and the length are around 50meters.

Meanwhile, its height is around the 16 meters. This design makes it viable to transport heavy cargo, as well as vehicles to different locations. For cargo operations our aircraft requires a crew of three: pilot, copilot, and loadmaster. The cargo compartment is 27m long by 5.5m wide and 3.7m high. The cargo door has rollers for palletized cargo but it can be flipped to provide a flat floor suitable for vehicles and other rolling stock.

The designed aircraft is powered by four Pratt Whitney F117-PW-100 turbofan engines, which are based on the commercial Pratt and Whitney

Following performances are affirmed for this Aircraft:

_ Take off from a 2243meter airfield

_ Carry a payload of up to 76000kg

_ Refuel while on flight in 914 meters or less on a small unpaved or paved airfeld in day or night.

_ Carry a cargo of wheeled vehicles in two side-by-side rows,

_ Drop a single 27216kg payload, with sequential load drops of 49895kg

Fuselage – The designed aircraft presents a semi-monocoque fuselage which allows a maximum profit of space to carry big elements such as trucks. Its structure is composed by approximately 74 formers which give the final shape to the aircraft's skin. There are also a few bulkheads which separates the different compartments of the aircraft and semi-bulkheads which support hydraulic systems.

Wing's structure – Its super critical airfoil to minimize the aircraft's drag is directly affected to its structural design. Two I-shaped spars are constructed from the root to the wing's tip. Between them, approximately 30 ribs are separated in 3 sections: the leading edge, which is formed by the first quarter of the wing's ribs, and present mobile devices to move the front flaps

Stabilizer's structure – The T-tail structure presents a multi-spar and rib fin structure which gives shape to the vertical stabiliser. They cross themselves to result in a rigid structure that is then given aeronautical features by semicircular ribs placed on the vertical leading edge. This structure commented is separated in two parts: the fixed vertical stabiliser and the rudder, which its height follows the proportion of the tail and leads itself to the trailing edge.

Engines – aircraft is powered by four fully-reversible Pratt & Whitney PW2000 series turbofans, designated as F117-PW-100 by the Air Force. Each engine is rated at 180kN of thrust and employs thrust reversers that direct the flow of air upward and forward to avoid ingestion of dust and debris.

Composite Materials – Sixteen-thousand pounds of composite materials have been applied to aircraft. Several of the major control surface and secondary structural components of the aircraft are made of composites. The most direct contribution to its applications was the development of componenets locates on upper aft rudders.

Landing Gear – landing gear system consists of a single nose strut with two wheels and two twin-strut tandem gear assemblies; each has one per side with three wheels per strut. The aircraft can takeoff or land just about anywhere in the world.

So, in the first part we discussed the main stages of desgine process and raised our requirments for choosing optimal prototype. Subsequently we ploted a table to present specifications such as operational-technical data and geometric parameters of three different aircraft (Boeing C-17 Globemaster III, Antonov An-124 Ruslan, Airbus A400M Atlas) and analaysd main charactersitics of each variant as well as their desgined layout . In the final phase we choose the prototype based on our initial data and briefly explained the main parts of the aircraft we plan to designe in this project.

1.3 Wing geometry calculation

In this project layout of the aircraft consists of structural body which allows a maximum profit of space to carry big elements such as tanks or trucks. Its structure is composed by formers, which gives the final shape to the aircraft’s skin. They are installed parallel to each other and are connected by side members along the entire perimeter of the surface. There are also a few bulkheads in our design which separates the different compartments of the aircraft and semi-bulkheads which support hydraulic systems, such as the pistons that open and close the back doors. Technologically fuselage devided into three parts: front (cockpit) middle (cargo compartment), rear (tail unit). The front part of the aircraft is separated in two floors, the lower one has the pilot's entrance and the second one contains the cockpit, as well as many electrical instruments and other devices or the landing gear's front wheel. The tail of the fuselage consists of smaller forms, spars and stringers which decrease in diameter. Separation and thickness of these forms is same as the rest of the fuselage (despite the cockpit). As the formers are smaller but its thickness is constant, they are more rigid so that there are no structural problems to support both the horizontal and vertical stabilisers.

The wing structure of this aircraft is airfoil with supercritical design to minimize the aircraft’s drag. The airfoil is constant along the wing which prevents the formation of torsion; wing root is aproximatly $\frac{1}{4}$ of the fuselage length. Figure 1.7 below is drawing of supercritical form of airfoil.

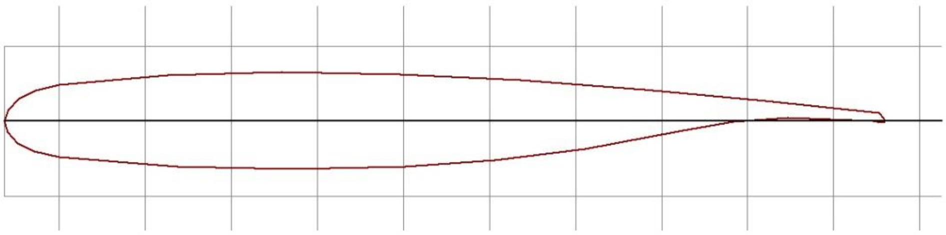

Figure 1.7 - The wing’s supercritical airfoil

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

Wing area is:

$$S_w = \frac{m_0 \cdot g}{P_0} = \frac{304901 \cdot 9{,}8}{6888} = 433{,}80\ (m^2)$$

We took $350м^2$. Wing span is:

$$l = \sqrt{S \cdot \lambda} = \sqrt{350 \cdot 7{,}67} = 51{,}81(m)$$

Root chord is:

$$b_o = \frac{2S_w \cdot \eta_w}{(1+\eta_w) \cdot l} = \frac{2 \cdot 304901.2{,}50}{(1+2{,}50) \cdot 51{,}81} = 9{,}65\ (m)$$

Tip chord is:

$$b_t = \frac{b_o}{\eta_w} = \frac{9{,}65}{2{,}50} = 3{,}86(m)$$

Board chord is:

$$b_{ob} = b_0 \cdot (1 - \frac{(\eta_w - 1) \cdot D_f}{\eta_w \cdot l_w}) = 8{,}88(m)$$

During calculation of wing structure we determine the number of spars, their position and their loccation on the wing as well. Relative position of the spars according to chord of wing is equal:

$$\bar{x}_i = \frac{x_i}{b},$$

where x_i – distance of i-spars to the tip of the wing, b – chord.

Between spars about 30 ribs are located in 3 sections, first section: leading edge contains quarter of wing's ribs and devices to move flaps. The Second section between two spars has largest thickness part of ribs which reinforced by stringers along the wing. Final section presents both electrical devices and statical parts. The wings ribs have holes inside their section for different advantages such as: lightening up of the weight and communication devices that placed along the wing.

I have used the geometrical method of mean aerodynamic chord determining (figure 1.8).

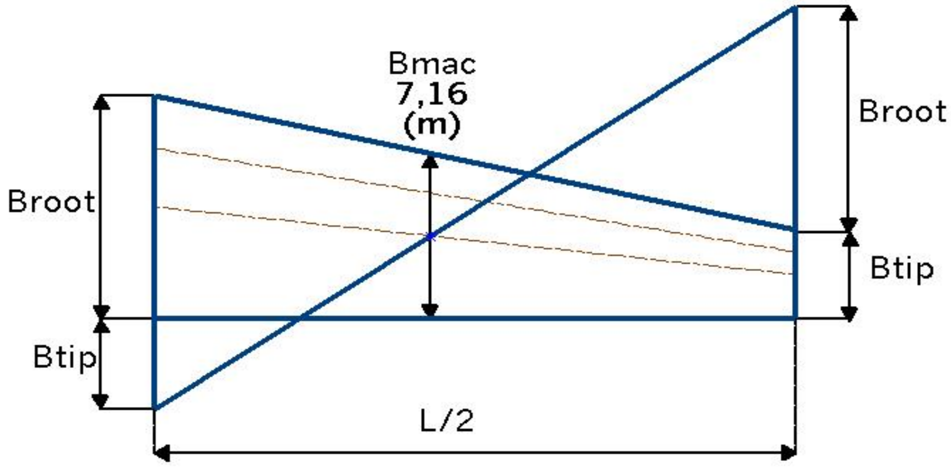

Figure 1.8 - Geometrical method of wing mean aerodynamic chord determination

Mean aerodynamic chord is equal b_{mac} = 7,16 m.

Next phase of calculation after deremination of geometric characteristic of the wing is geometry of ailerons and high-lift devices that belongs to wing The geometric parameters of the ailerons are determined in next order :

Ailerons span:

$$l_{ail} = 0,35\frac{l}{2} = 0,35 \cdot \frac{51,81}{2} = 9,066\,(\text{m})$$

Ailerons chord:

$$b_{ail} = (0,22\ldots0,26)\cdot b_i;$$

Aileron's area:

$$S_{ail} = (0,05\ldots0,08) \cdot \frac{S_{кр}}{2} = 0,06\frac{350}{2} = 10,5\ (\text{m}^2)$$

Aerodynamic compensation of the aileron.

$S_{axinail} \leq (0.25\ldots0.28)\ S_{ail} = 0{,}25 \cdot\ 10{,}5\ =\ 2{,}62(\mathrm{m}^2)$

Inner axial compensation

$S_{inaxinail} = (0.3..0.31)\ S_{ail} = 0{,}3 \cdot 2{,}62 = 0{,}795\ (м^2)$

Area of ailerons trim tab for two engine airplane:

$$S_{\mathrm{tail}} = 0{,}04\ldots0{,}06 \cdot S_{\mathrm{ail}} = 0{,}05 \cdot\ 10{,}5 =\ 0{,}525(\mathrm{m}^2)$$

The range of aileron deflection are: upward $\delta_{ail} \geq 35^{\circ}$; downward $\delta_{ail} \geq 25^{\circ}$.

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

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

1.4 Fuselage layout

In order to selecet fuselage parameters, it is obligatory to follow the aerodynamics requirements (streamlining and cross section).

Using transonic cargo aircrafts (V < 800 km/h) wave resistant doesn’t have impact in order of aerodynamic performance. That's why we need to choose friction resistance C_{xf} and profile resistance C_{xp} from the conditions of the listed values.

Nose part of fuselage for subsonic aircraft:

$$l_{nfp} = 2{,}5 \cdot \mathrm{D_f} = 2{,}5 \cdot 6{,}86 = 17{,}15(\mathrm{m}),$$

where $\mathrm{D_f}$ – diameter of a fuselage.

With the aerodynamic requirements consideration due to choosing of cross section shape, we need to consider the strength and layout requirements.

The most effective fuselage cross section is circular cross section to ensure it has minimal weight. In this partial case we may use the combination of two or more vertical or horizontal parts of circles to form the fuselage structure.

For cargo aircrafts the aerodynamics has less importance for the selection of fuselage shape, and the cross-section shape may be close to rectangular.

Geometrical parameters used in calculation are as following: fuselage diameter D_f; fuselage length l_f; fuselage aspect ratioλ_f; fuselage nose part aspect ratioλ_{np}; tail unit aspect ratioλ_{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.

Determination the length of the fuselage:

$$l_f = \lambda_f \cdot D_f = 7{,}72 \cdot 6{,}86 = 52{,}95(m);$$

Determine the length of the nose: $l_{fnp} = \lambda_{fnp} \cdot D_f = 2{,}5 \cdot 6{,}86 = 17{,}15(\mathrm{m});$

Determine the length of the rear part: $l_{frp} = \lambda_{frp} \cdot D_f = 3{,}5 \cdot 6{,}86 = 24{,}01(\mathrm{m}).$

Fuselage nose part aspect ratio is equal:

$$\lambda_{fnp} = \frac{l_{fnp}}{D_f}; \frac{17{,}15}{6{,}86} = 2{,}5$$

Fuselage rear part aspect ratio is equal:

$$\lambda_{frp} = \lambda_f - \lambda_{fnp}$$

At the stage of sketch designing to determine the length of the fuselage, we can recommend the ratio for next airplanes:

With a sweepback wing: l_f / l_w= 0,8…0,95, if λ_w = 8…10;

with X^0 – $35° \ldots 45°$: l_f / l_w= 0,95…1,25, if λ_w = 3…5.

For cargo airplanes fuselage mid-section comes from the size of cargo cabin compartment. One of the main parameter to determine is the mid-section of the height of the cargo compartment.

For mid-range airplanes according the following: the height: h_1=1.9m; passage width b_p=0.6m; the distance from the window to the flour h_2=1m; luggage space h_3=0.9...1.3m.

It should be taking into account that finding the required cargo compartment width does not yet allow you to find the optimal dimensions of the cross-section of the fuselage. From the constructive point of view it is rational to have a circular cross-section of the fuselage, because in this case it will be the strongest resistant and lightest weight.However, this form may not always be optimal for cargo transformation.

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

Form the design consideration with the diameter less than 2800 mm we don’t use such shape and we follow to the intersecting circles cross section.

The crew cabin doesn’t need to be very large in cargo airplane, at the same time it demand to prepare comfortable workplace for the the flight crew. The most precise requirements are imposed on pilot's working place. In addition to convenience, it should contain overall owerview to outside area. The size of the service cabin depends on the composition of the crew. On mid range aircrafts, the crew consist of pilot, copilot, and loadmaster, Pilots are placed in the seats nearby, the copilot for the visual connection between him and the loadmaster. The cabin of the flight crew is separated from other rooms by a rigid divider with a lockable door.There are controls, computers, systems, instruments, and another equipment inside the cabin.

The cabin known as comfortable if it provides a forward-looking seating for the crew members. They are designated and adjusted in horizontal and vertical directions.

These seats are usually mounted on tracks to maintain esay entrance for crew member and as saftety used seat belts with high resistance material to avoid tupture of belt in emergency situation

Glass part of crew cabin made of two kinds of windows: side and front Side windows are divided into sliding (left and right) and fixed side windows (left and right). The front windows consist of a windshield and windows for the eyes.The windshield is very durable, it is made of composite glass that has good optical and aerodynamic characteristics it equipped with functional heaters and glass cleaner to protect glasses from icing. In condition of heavy raining there is a rain repellent liquid which stored in pressurized bottle would be sprayed on windshield to improve visibility of crew

The configuration of the workplaces of the pilots encompass all emergency requirment. The controllability and stability characteristics of the aircraft, the structure, characteristics and automation of flight navigation equipment and on-board systems, the structure and configuration of the display equipment ensure that pilots perform their duties without exceeding the existing load standards.

The placement of instruments and light-signaling devices on the pilot's control panel is perform under regulation of airworthiness standards . On the upper control panel in the zone best reach recives and visibility are located the quickly used control panels for command radio stations and automatic control systems.

The upper control panel of the onboard systems contains the hydraulic, fuel, power supply, air conditioners, anti-icing system, engine and APU starting, alarm panel and fire extinguishing switches.

On the poilots middle panel we have engine control levers as well as navigation and landing gear operational panels. There is also a control pedal under the crew's foot which controls position of rudder for vertical axes yaw movment.

To provide easy accessibility to functional handeles and levers we must observe several standardization and requirement, to mention few, first all levers and handeles must locate in visible zone to optimize working area the size and color must be recognizable for crew to avoid mistake in emergency conditions.

Designed aircroft has one floor cargo compartment that is capable of transferring cargo and people (soldiers or patients) to another location. Cargo hold floor equipped with several systems that provides mechanical advantage for loading and unloading and also Prevents movement of cargo during flights or emergencies.

Wheel chocks: this aircraft is capable of transferring heavy vehicles such as tank or trucks, in order to avoid accidental movement of vehicles we use wheel chocks against its wheels.material used under these chocks is rubber to make ressitance and grib the floor.

Tie down device: they are intending to connect cargo, inside cargo hold to the jacks of the ground floor or ramp, with help of equipments such as locks, chain, belts.

Overhead equipment (telpher): it consists of electric- run cabale to transfer cargo along overhead path. Telphere has a pendant control which controls the hoist in vertical direction and whole system in horizontal direction along I beams installed on ceiling of cargo hold. Hoist drum has a block that connects to the hook at the end, to transfer cargo we connect it safely with a help of chains to this hook and by the use of control we are able move it along cargo compartment to different directions.

Ranges of weights and centers of gravity whithin which airplane maybe safely operated must be established.if a weight and center of gravity combination is allowable only within certain load distribution limits(such as spanwise) that could inadvertently exceeded, these limits and corresponding weight and center of gravity combination must be established.

The extreme forward and extreme aft centre of gravity limitation must be established for each practicably seperable operating condition

Each compartment for the stowage of cargo, baggage, carry-on articles, equipment(such as life rafts), and any other stowage compartment must be designed for its placarded maximum weight of contents and for the crtitical load distribution at the appropriate maximum load factors. Corresponding to the specified flight and ground load conditions, and to the emergency landing conditions, except that the forces specified in the emergency landig condtions need not be applied to compartments loacated below, or forward, of all occupants in the airplane.

Given the fact that the unit of load on floor K = 400… 600 kg/m^2

The area of cargo compartment is defined:

The cargo compartment is 27 m long by 5.5 m wide by 3.76 m high.

Volume of cargo compartment 559 m^3

1.5 Tail unit design

The T-tail structure constructed by a multi spar and rib fin structure which gives shape to vertical stabilizer.they cross themselves to produce a rigid structure that permit aeronautical features by semicircular ribs placed on the vertical leading edge. The structure mentioned is consisting of two parts: the fixed vertical stabilizer and the rudder, which its height follows the proportion of the tail and leads itself to, trailing edge.

Regarding the horizontal stabilizer, its structure desgine is similar to wings designe.There are two sparsed known as H-shape disparate in three sections, aproximatly 19 ribs per side.

Rudder made a two-tier, three-section (lower, upper and middle sections) and is made mostly of composite materials. As nodes rudder linkage made removable covers for the construction inspection, repair and maintenance, and replacement of all mechanical parts. In plumage provided protection structure against deterioration or loss of strength of environmental influences in all anticipated operating conditions, and also have ventilation and drainage in all compartments.

According to given data we might find the first approach of geometrical parameters determination.

Area of vertical tail unit is equal:

$$S_{vtu} = (0{,}12\ldots0{,}2) \cdot S_w;$$

Area of horizontal tail unit is equal:

$$S_{htu} = (0{,}18\ldots0{,}25) \cdot S_w;$$

Much better could be calculated like:

$$S_{htu} = \frac{b_{mah} \cdot S}{L_{htu}} \cdot A_{htu} = \frac{7{,}16 .350.0{,}7}{3{,}3.7{,}16} = 74{,}24\ (m^2)$$

$$S_{vtu} = \frac{l \cdot S}{L_{vtu}} \cdot A_{vtu} = \frac{7{,}16 .350.0{,}1}{3{,}2.7{,}16}. = 78,\ 31\ (m^2)$$

Values L_{htu} and L_{vtu} are influenced on various factors such as thelenght of the nose section, tail segment of fuselage, sweepback angle, location of wind and from point of performance, condition of stability and controllability of the airplane.

In the first approach we may count that $L_{htu} \approx L_{vtu}$ =22,9

Trapezoidal scheme, normal scheme $L_{htu} = (0.2...3.5) \cdot b_{mac\ =}$ 7,16

For heavy airplane $L_{htu} = (3.2...3.3) \cdot b_{mah}$

So, $A_{htu} = 0{,}7$; $A_{vtu} = 0{,}1$

Determination of the elevator area and direction. Altitude elevator area:

$$S_{ea} = 0{,}345 \cdot S_{htu} = 26{,}61(m^2)$$

Rudder area:

$$S_{rd} = 0{,}4 \cdot S_{vtu} = 0{,}4 \cdot 78{,}31 = 31{,}32(m^2)$$

Elevator balance area is equal:

$$S_{eb} = (0{,}22\ldots0{,}25) \cdot S_{ea} = 6{,}12(m^2)$$

Rudder balance area is equal:

$$S_{rb} = (0{,}2\ldots0{,}22) \cdot S_{rd} = 6{,}57\ (m^2)$$

The area of elevator trim tab:

$$S_{te} = 0{,}1 \cdot S_{elv} = 0{,}1 \cdot 26{,}61 = 2{,}61(m^2)$$

And for rudder of the aircraft with six engines $S_{ttea} = (0.04..0.06) \cdot S_{ea}$, for the aircraft with four engines:

$$S_{tr} = 0{,}04 \cdot S_{rud} = 1{,}25(m^2)$$

In the formula above the lower limit corresponds to the turbofan engine aircrafts, equipped with all-moving stabilizer

The height of the vertical tail unit h_{vtu} is determined according to the location of the engines. Taking into account assumption:

Engine in the root part of the wing $h_{vtu} = (0.13..0.165) \cdot l_w$

Height of the vertical tail unit is equal:

$$l_{vtu} = 0,2 \cdot l_w = 10,36 \text{ (m)}$$

For airplanes with high wing, we have to set the upper limit.

Recommendation to choose, tapper ratio of horizontal and vertical tail unit:

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

Tail unit aspect ratio we may recommend:

For transonic planes $\lambda_{vtu} = 0.8...1.5$; $\Lambda_{htu} = 3.5...4.5$

Determination of tail unit chords b_{ends}, b_{MAC}, b_{root}.

Horizontal tail unit tip chord:

$$\mathrm{b_{tchtu}} = \frac{2 \cdot S_{htu}}{(\eta_{htu} + 1) \cdot l_{htu}} = 2,3\text{(m)}$$

Vertical tail unit tip chord:

$$\mathrm{b_{tcvtu}} = \frac{2 \cdot S_{vtu}}{(\eta_{vtu} + 1) \cdot l_{vtu}} = 5.03\text{(m)}$$

Horizontal tail unit root chord:

$$\mathrm{b_{rchtu}} = \mathrm{b_{tchtu}} \cdot \eta_{htu} = 10,22\text{(m)}$$

Vertical tail unit root chord:

$$b_{rcvtu} = b_{tcvtu} \cdot \eta_{vtu} = 5(m)$$

Horizontal tail unit mean aerodynamic chord:

$$b_{MAChtu} = 0{,}66 \cdot \frac{{\eta_{htu}}^2 + \eta_{htu} + 1}{\eta_{htu} + 1} \cdot b_{tchtu} = 5{,}01(m)$$

Vertical tail unit mean aerodynamic chord:

$$b_{MACvtu} = 0{,}66 \cdot \frac{{\eta_{vtu}}^2 + \eta_{vtu} + 1}{\eta_{vtu} + 1} \cdot b_{tcvtu} = 9{,}45(m)$$

Regarding that stablilizing and fixing of aircraft could be task of fin, we suppose to use upper limit of C_{tu}, to provide fixation base on the fin. Tail unit sweptback is not more than wing sweptback. We do it to provide the control of the airplane in shock stall on the wing.

1.6 Landing gear design

Aircraft landing gear consists of six wheels in main on each side and one front support.

Each main support consists of shock struts, on which two wheels with hydraulic discbrakes and wheels fan cooling system are fitted.

Main supports are retracted in compartments of the fairing towards the plane of symmetry of the aircraft.

Nose landing gear consists of a controlled shock thrust with two non-braking wheels. The front support is retracted into the front compartment of the chassis against the fuselage of the airplane. Compartment is closed by doors.

Landing gear for this aircraft consists of following mechanical subsystems:

- Retraction and extension;
- Wheel braking;

- Temperature control and wheel cooling control;
- Control of front landing gear turning;
- Retraction and extension and elongation of auxiliary support;
- Adjusting of the load floor height.

The main functions of landing gear are:

- To keep the aircraft stable on the ground and during loading, unloading and taxi;
- To allow the aircraft to freely move and maneuver during taxing;
- To provide a safe distance between other aircraft components such as wing and fuselage while the aircraft is on the ground.

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 could be determined.

Main wheel axel offset is:

$$e_g = 0{,}2 \cdot b_{MAC} = 0{,}2 \cdot 7{,}16 = 1{,}43(\mathrm{m})$$

With the huge wheel axial offset the lift-off of the front gear during take off is involved. Having said that with small type also the dangerous of falling airplane on the tail is possible, when we consider back loadings on the airplane as priority. Landing gear wheel base comes from the expression:

$$B_g = (0{,}3\ldots0{,}4) \cdot l_f = 0{,}35 \,.\ 52{,}92 = 18{,}53(\mathrm{m})$$

Large value belongs to the airplane with the engine on the wing (EonW).

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

Front wheel axial offset will be equal:

$$d_{ng} = B_g - e_g = 18{,}53 - 1{,}43 = 17{,}10\ (m)$$

Wheel track is:

$$K_{wt} = 0{,}6 \cdot B_g = 0{,}6 \cdot 18{,}53 = 11{,}11\ (m)$$

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

Wheels for the landing gear is chosen by the size and run loading from the take off weight; for the front wheel support we consider dynamic loading as well.

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

The load on the wheel is determined: K_g = 1.5...2.0 – dynamics coefficient.

Nose wheel load is equal:

$$P_{nlg} = \frac{e_g \cdot m_0 \cdot g \cdot K_g}{B_g \cdot z_{nlg}} = 201768{,}60\ (N);$$

Main wheel load is equal:

$$P_{mlg} = \frac{(B_g - e_g) \cdot m_0 \cdot g}{B_g \cdot z_{mlg} \cdot n_{mlg}} = 229786{,}42\ \ (N).$$

By calculating P_{main} and P_{nose} and the value of $V_{take\ off}$ and $V_{landing,}$ pneumatics is chosen from the catalog, the following correlations should correspond.

$$P^K_{slmain} \geq P_{main}; P^K_{s\ln ose} \geq P_{nose}; V^K_{landing} \geq V_{landing}; V^K_{takeoff} \geq V_{takeoff}$$

We select the wheel to the nose and main supports (table 1.3):

Table 1.3 – Tires for the landing gear of designined aircraft

Wheel size	$P_{ст.взл}$, H	$P_{ст.пос}$, H	$P_{о}$, 10^5Pa	$\delta_{ст}$, mm	$P_{разр}$, H	$V_{пос}$, km/h	$V_{взл}$, km/h
For main support of chassis							
1100×330B	110000	86000	10	81	540000	260	330
For nose support of chassis							
1000×280B	66000	5750	10	65	345000	240	330

1.7 Choice and description of turbofan engine

Pw2000 also known by the military designation F117 and initially referred to as the JT10D, is a series of high-bypass turbofan aero engines with a thrust range from 160 to 190 kN.The PW2000 is a dual-spool, axial air flow, annular combustion, high bypass turbofan with a dual-channel Full authority digital engine control (FADEC) system. A single-stage fan and four-stage, axial low-pressure compressor are driven by the five-stage, uncooled, axial low-pressure turbine. The 12-stage axial compressor is driven by the two-stage axial turbine. Stages 1-5 have variable stators. The last eight stages of the high-pressure (HP) compressor employ active clearance controls. Blades are designed and manufactured with thicker leading edges and are form for greater efficiency. A single annular nickel alloy combustor employs 24 single-orifice, airblast fuel nozzles. The HP turbine includes two axial stages. The fan and low-pressure compressor are direct-driven by the supercharged, five-stage uncooled axial turbine.

General characteristics:

Type: Turbofan

Length: 3,729 mm

Diameter: 2,146 mm

Dry weight: 3,221 kg

Components:

Compressor: Axial, 1 stage fan with 36 blades, 4 stage LP, 12 stage HP

Combustors: Annular

Turbine: 2 stage HP, 5 stage LP Fuel type: Jet-A, Aviation kerosene

Performance:

Maximum thrust: 38,400–43,734 lbf (170.81–194.54 kN)

Overall pressure ratio: 27.6-31.2:1

Bypass ratio: 5.9

Thrust-to-weight ratio: 5.41-6.16

Major applications: B 757, Boeing C-17 Globemaster III, Ilyushin Il-96M.

1.8 Determination of the aircraft centre of gravity position

1.8.1 Determination of the mass power of the equipped wing

Equipped wing carries 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 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 point of the mean aerodynamic chord (MAC) for the surface XOY.

The example list of the mass objects for the aircraft, where the engines are located in the end part of the fuselage, included the names given in the table 1.4.

Table 1.4 - Trim sheet of equipped wing masses

N	Name	Mass		C.G. coordinates, m	Mass Moment, (kgm)
		Units	total (kg)		
1.	Wing (structure)	0,0768	234163968	2,8	65565,911
2.	Control system, 30%	0,00093	283,55793	4,29	1216.46352
3.	Electrical equip. 10%	0,00118	359,78318	0,716	257,604757
4.	Anti-icing system 70%	0,00742	2262,36542	0,514	1162,85583
5.	Hydraulic system, 70%	0,00693	2112,96393	2,8	5916,299
6.	Power plant	0,10368	31612,13568	-4.2	-132770.97
7.	Fuel system	0.0102	3109,9902	2,86	8894,57197
	Equipped wing without landing gear and fuel	0,20714	3157,19314	3.416629	215784.676
8.	Fuel	0,31344	95568,16944	2,5	238920,424
	Total	0,52058	158725,362	2,864	454705,1

1.8.2 Determination of the mass power of the equipped fuselage

The origin of coordinate’s chosing in the projection of the nose of the fuselage on the horizontal axis. For the axis X the construction part of the fuselage is given. The example list of the objects for the aircraft, which engines are mounted to wing, is given in table 1.5.

Table 1.5 - Trim sheet of equipped fuselage masses

№	Name	Mass m_i		C.G. coordinates, m	Moment (kgm)
		Units	total (kg)		

1.	fuselage	0,08195	24986,63	18,2	454756,792
2.	horizontal tail	0,00917	2795,94	45	125817,398
3.	vertical tail	0,01041	3174,01	43,5	138069,844
4.	anti icing sys 15%	0,00159	484,79	24,5	11877,4185
5.	air conditioning 15%	0,00159	484,79	26,4	12798,5244
6.	heat and sound isolation	0,0043	1311,07	26,4	34612,3615
7.	aircraft control system 70%	0,00217	661,63	26,4	17467,1685
8.	hydraluic sys 30%	0,00297	905,55	25,6	23182,2328
9.	electrical equipment	0,01062	3238,04	24,5	79332,1912
10.	radar	0,0039	1189,11	1	1189,1139
11.	air-navigation system	0,0053	1615,97	2	3231,9506
12.	radio equipment	0,0029	884,21	2	1768,4258
13.	instrument panel	0,0068	2073,32	4	8293,3072
14.	cargo cabin eq	0,0001	30,49	22,3	679,92923
15	furnishing eq	0,0433	13202,21	22,3	294409,357
16	non typical equipmen	0,0023	701,27	22,3	15638,3723
17	Nose landing gear	0,008146	2483,72	2,5	6209,30887
18	Main landing gear	0,032584	9934,89	22,2	220554,651
19	equipped fuselage without payload	0,2301	70157,72	20,66613	1449888,35
20	mail/cargo	0,2412	73542,12	10	735421,212
22	Crew	0,00817	2491,04	2	4982,08234
Total		0,47947	146190,88	14,98241	2190291,64
TOTAL fraction: 1,00005					

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

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

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

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

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

$$X_{MAC} = \frac{m_f x_f + m_w \cdot x_w^{/} - m_0 C}{m_0 - m_w} = 13{,}61 \text{ (m)}$$

where m_0– aircraft takeoff mass, kg; m_f – mass of fully equipped fuselage, kg; m_w – mass of fully equipped wing, kg; C – distance from MAC leading edge to the C.G. point, determined by the designer. C = (0,23...0,32) b_{MAC} – high wing; for swept wings; at X = 30°...40° C = (0,28...0,32) b_{MAC}, at X= 45°C = (0,32...0,36) b_{MAC}. In practice, the center of the plane is determined, as a rule, in relative coordinates X_t, that is, the position of the center of mass from the beginning of the leading edge of mean aerodynamic chord, expressed as a percentage (or fraction).

$$\bar{x}_T = \frac{x_T - x_A}{b_A} 100\%$$

Therefore, to compute the centering of aircraft $\bar{x}_T$ it is necessary to know the position of the beginning of the mean aerodynamic chord of the wings relative to the fuselage x_a. Initial value x_a can be determined through the appropriate scale from the scheme of the prototype aircraft, having previously determined the size of the center of mass and drawn it on the wing

In the case that these values can not be obtained, it is recommended to apply the following means of correction center: change the location of the heaviest loads in the fuselage; move the wing along the fuselage (with this will move not only the center of the mass of the plane, but also the center of mass of the wings).

In order to facilitate the implementation of calculations of centre of gravity positions, it is recommended that the masses and corresponding coordinates of the masses be reduced to the table in Table. 1.6.

Table 1.6 - Center of gravity position variants

Name Object	Mass, kg	Coordinates	Moment,

	m_i	C.G., m	kgm
Equiped wing	63157.1931	13.87	876024.7
Nose landing gear (extended)	2483.72355	2.5	6209.309
Main landing gear (extended)	9934.89418	22.2	220554.7
Fuel	80441.802	16.11	1296258
Equipped fuselage	70157.7201	20.66	1449888
Crew	2491.04117	2	4982.082
Nose landing gear (retracted)	2483.72355	3.5	8693.032
Main landing gear (retracted)	9934.89418	23.2	230489.5

Mandatory variants of calculation of the center of the aircraft for the most typical cases of aircraft operation are summarized in Table 1.7.

For the landing variant, the mass of fuel can be roughly taken 15% ... 20% (depending on the type of airplane) from the mass of fuel during take-off, and for the overhead - the mass of fuel is maximally possible (due to lack of commercial load) and is determined by the capacity of the fuel tanks of the aircraft.

Table 1.7 - Airplane's centre of gravity position variants

Name of objects	Mass, kg	Mass Moment, kgm	C.G.,	Centering, %
Take off mass (LG extended)	304901	4589338.307	15.05	20.08
take off mass (LG retracted)	304901	4601756.925	15.09	20.65
landing weight (LG extended	236893.06	3536830.083	14.93	18.38
ferry version	256211.35	3866335.713	15.09	20.62
parking version	145733.53	2552676.959	16,04	22.28

Conclusion to the part

In this main part of diploma work, firstly with given data we were able to calculate major geometrical parameters to construct structre of aircraft. Parameters that were examined : wing geometry characteristic (we used geometrical method to determine mean aerodynamic chord), fuselage lyout, tail unit and landing gear.formulas that choosed in this project to detmine value of mentiond structure, all based on characteristic of our prototype. Next we took turbofan engine named Pratt & Whitney PW2000 and mentiond specifications and major application of this type engine on other aircrafts. Finaly For the designing of our aircraft we have calculated the Center of Gravity position, masses of wing, fuselage and airplane's C.G. position variation.

2. CONCEPTUAL DESIGN OF PALLET

2.1 Pallet, construction, description and equipments

Unit load devices (ULD) pallets are rugged sheets of aluminum with rims designed to lock onto cargo net lugs. Before development of ULD, individual pease of cargo were loaded into airlifter by use of group of people that had many disadvantages. The time consuming process was one of the most important problems especially for military- transport aircrafts that speed of action plays an important role in emergency situations. The device which designed in this project for cargo handling system of designed airplane is pallet.

This pallet structured as a metal - sandwich composite construction which is special class of composite material that consist of two thin layer of metal skin attached to a lightweight, thick core in the middle. The core material used is balsa wood which is low strength material but its higher thickness provides the sandwich composite with high bending stiffness and low density.

The pallet made of corrosion-resistant aluminum (aluminum 5052) as its constituent face sheets or skins and framed on all sides by aluminum rails. Overall the pallet build with 22 tie down rings that divide into 6 attached rings on each long side and 5 rings on each short side.

2.2 Dual-rail system

Dual rail system installed in most of transport aircraft. It consists of rows of rollers that facilitate movement of palletized cargo into cargo hold. Many of these rollers are stowable to convert the cargo deck to a flat, providing clear loading surface for wheeled cargo. The side rails guide the pallets into the aircraft and provide lateral and vertical restraint. These rails are equipped with locks (known as detent locks) that hold the pallet securely in place while it’s inside the aircraft. These locks also prevent the forward and aft movement of pallets duringflight. Dual rail and its guide system shown in figure 2.1 and figure 2.2.

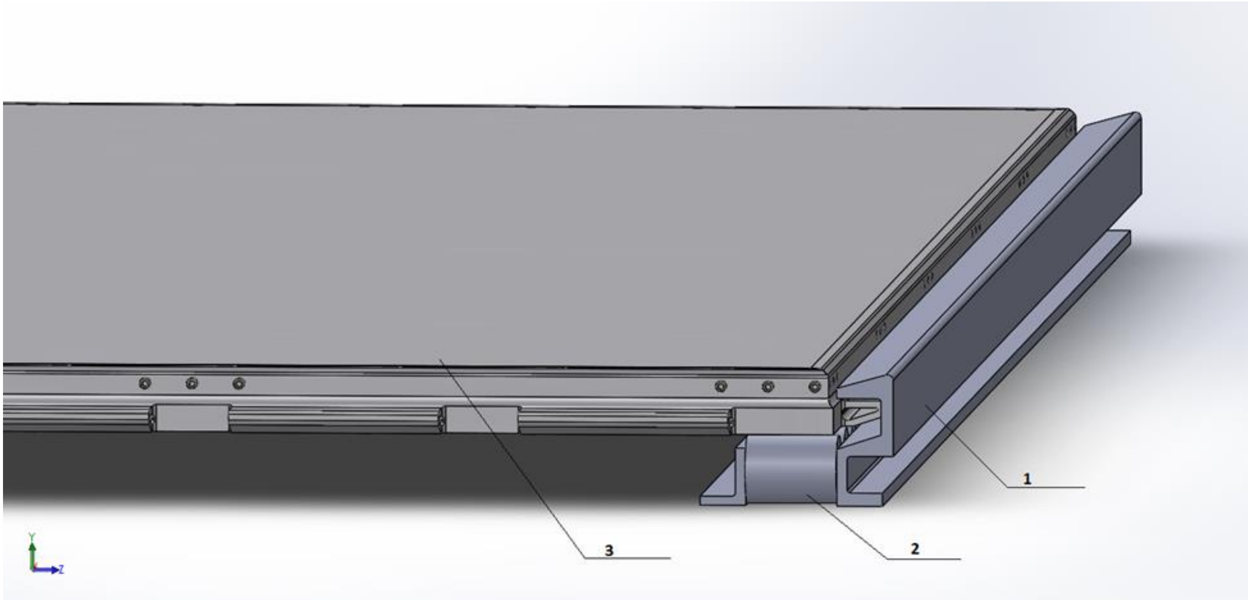

Figure 2.1 - Pallet attached to side guide rail system at the end. 1- Side guide rail, 2- Roller, 3- Pallet

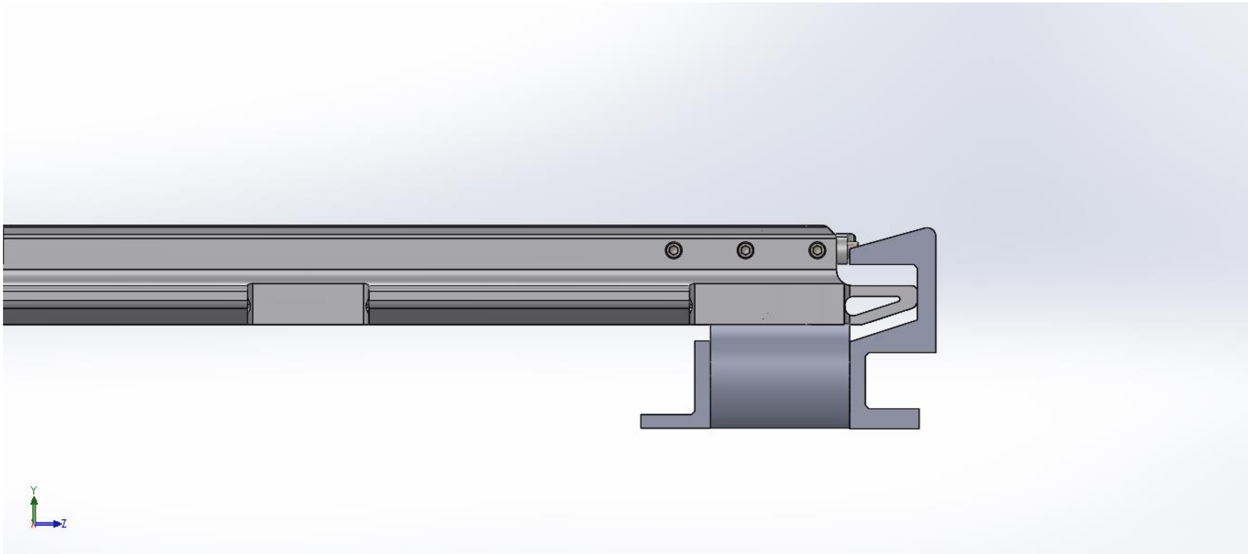

Figure 2.2 - Front view of attached pallet to side guide rail system

2.3 Pallet nets

The pallet equipped with three net to set up: One covers upper part of cargo known as top net with yellow color and two green side nets. Side nets directly connect to side rings of the pallet but the top net attaches by hook to the rings on side nets. The nets have multiple adjustment points and could be tightened adequately on loads with disparate shapes. Pallet nets and attachments are shown in figure 2.3.

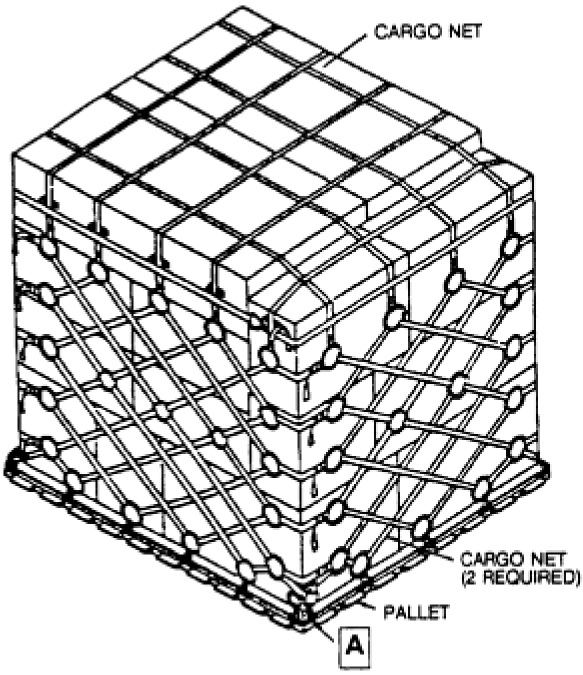

Figure 2.3 - Pallet nets and its attachments

Material used to manufacture these netes is polyester and complete set of nets provides adequate restraint for 4000kg of cargo when connected properly to pallet.

2.4 Power driven unit

Power driven units (PDUs), located on the floor of an airplane's cargo bay and operated by a controller on the wall, a power driven wheel or tire engages the undersurface of a cargo pallet for horizontally moving the cargo in different directions to the appropriate position inside the airplane by moving back and forth and around.

A drvie motor coupled to drive roller selectively rotates the drive roller in two opposed directions.a reaction member connected to the drive motor is at least partially movabley engaged with deck support structure to permit at least some pivotial movement of the yoke and to substantially prevent rotation of the drive motor relative to the yoke.

The directional positioning mechanism of the power drive unit (figure 2.4) retains the tire in partial frictional engagement with the undersurface of the cargo container while the directional movement of cargo container is changed in order that the cargo container is retained under positive control at all times. This is necessary when loading or unloading an aircraft on a pitching and rolling aircraft carrier deck, or where the floor of the cargo compartment is unlevel. The operation of retracting and changing the directional orientation of the powered wheel drive unit, relies on the interaction of a dual cam system, which provides for a two-step controlled lowering of the powered wheel, in addition to a rotation thereof about a vertical axis, for a change in the directional movement of the cargo.

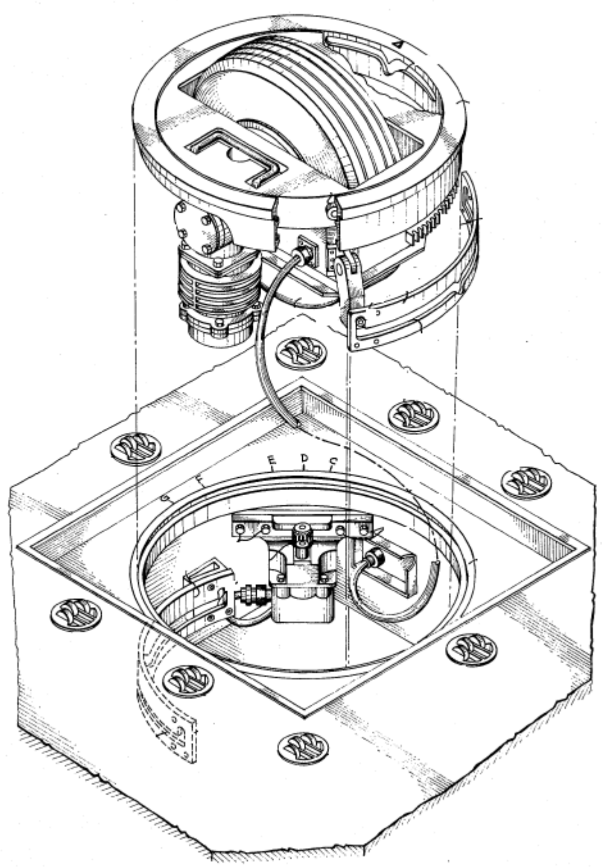

Figure 2.4 - Power driven unit

2.5 Strength calculation of locks attached in pallet

Determination of the external loading from cargo on pallet (figure 2.5):

Wight of cargo: M = 3800(kg);

Weight of a net: Mn = 30 (kg);

Weight of empty pallet: m = 170 (kg);

Total weight: G_{Σ} = 4000 (kg);

Force: F = m.a = 4000 . 9.8 = 39200N

Design case: finding number of supports require for safty of cargo.

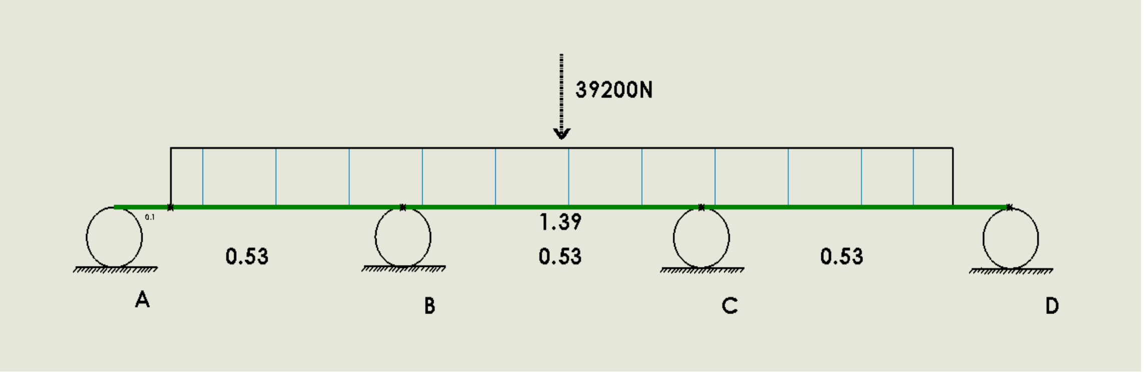

Figure 2.5 - Side view of pallet as beam on 4 support

External force of 39200 N applies to the beam with 4 supports, the equation of reactions become staticaly inderminate; to find the reactions and bending momment of each span we used moment distribiution method.

I – Fixed end moment:

FEM AB = $- \frac{pab^2}{l^2} = - \frac{12126,68 .\ 0,315 . 0,215^2}{0,53^2} = -628,60\ (\frac{N}{cm})$

FEM BA = $\frac{pa^2\ b}{l^2} = \frac{12126,68 . 0,315^2 .\ 0,215}{0,53^2} = 920,979(\frac{N}{cm})$

FEM BC = $- \frac{ql^2}{12} = \frac{14946,53 . 0,53^2}{12} = -349,87\ (\frac{N}{cm})$

FEM CB = $\frac{ql^2}{12} = 349,87\ (\frac{N}{cm})$

FEM CD = $- \frac{pab^2}{l^2} = - \frac{12126,68 . 0,315^2 .\ 0,215}{0,53^2} = -920,979\ (\frac{N}{cm})$

FEM DC = $\frac{pab^2}{l^2} = \frac{12126.68 .0.315.0.215^2}{0.53^2} = 628.60\ (\frac{N}{cm})$

II – Distribiution factors.

In this case joint is being released and begins to rotate under unbalanced moment threfore resisting forces develop at each member framed together at the joint. Although the total resistance is equal to the unbalanced moment the magnitudes of resisting forces developed at each member differ by the members' bending stiffness

Df = $\frac{k}{\sum k}$

K = $\frac{I}{L}$

EI = constant

$DF_{BA} = \frac{\frac{3}{4}(\frac{I}{0,53})}{\frac{3}{4}\left(\frac{I}{0,53}\right)+(\frac{I}{0,53})} = 0,428$

$DF_{BC} = \frac{(\frac{I}{0,53})}{\frac{3}{4}\left(\frac{I}{0,53}\right)+(\frac{I}{0,53})} = 0,571$

$DF_{CB} = \frac{(\frac{I}{0,53})}{\left(\frac{I}{0,53}\right)+\frac{3}{4}(\frac{I}{0,53})} = 0,571$

$DF_{CD} = \frac{\frac{3}{4}(\frac{I}{0,53})}{\left(\frac{I}{0,53}\right)+\frac{3}{4}(\frac{I}{0,53})} = 0,428$

Distribution of moment to detrmine shear force and reaction on each support are presented in the table 2.1.

$M_{AB} = 0$

M_{BA} = 708,261 = 708,261 $\frac{N}{m}$ (c.w)

M_{MC} = -708,261 = 708,261$\frac{N}{m}$ (c.c.w)

M_{CB} = 687,778 = 687,778 $\frac{N}{m}$ (c.w)

M_{CD} = -687,778 = 687,778 $\frac{N}{m}$ (c.c.w)

$M_{DC} = 0$

Table 2.1. - Distribution of moment to detrmine shear force and reaction on each support

SPAN	AB	BA	BC	CB	CD	DC
DF	0	0,428	0,571	0,571	0,428	0
FEM	-628,60	920,979	-349,87	349,87	-920,97	628,60
BAL	628,60	314,3			-314,30	-628,60
COM BAL		-378,955	-505,568	-252,784		
			324,951	649,903	517,873	
		-139,458	-186,052	-93,026		
			18,11	36,220	27,149	
		-7,89	-10,527	-5,26		
			1,52	3,040	2,278	
		-0,659	-0,879	-0,439		
			0,127	0,254	0,190	
		-0,0552	-0,0736			
SUM	0	708,261	-708,261	687,778	-687,778	0
DIR V	4919,32	7207,36	7473,265	7473,265	7207,36	4919,32
AUX V	1336,34	1336,34	38,6	38,6	1297,69	1297,94
TOTAL V	3582,979	8543,7	7511,865	7434,665	8505,054	3621,626
RXN	3582,979 RA	16055,565 RB		15939,719 RC		3621,626 RD

III – Calculation of direct and auxilary shear. The scheme of span loading are presented on the figures 2.6-2.8.

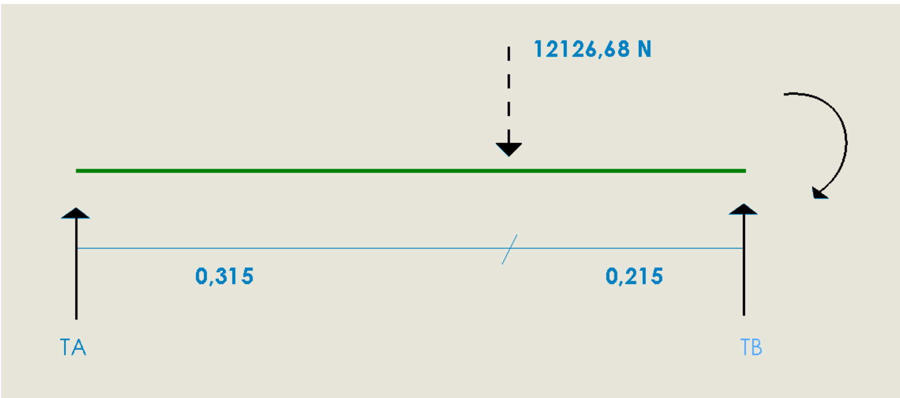

Figure 2.6 - Sheme of span 1 loading

$$TA\,.\,(053) = 12126{,}68\,.\,0{,}315$$

$TA = 7207{,}36$

TB = 12126,68 – 7207,36 = 4919,32

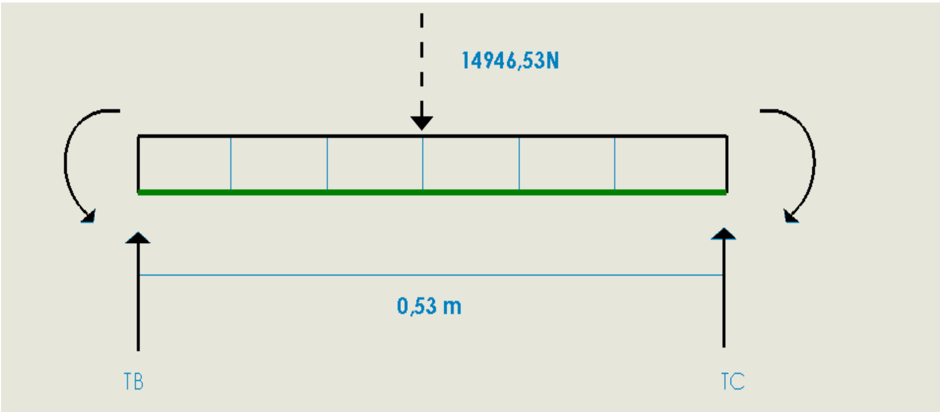

Figure 2.7 - Sheme of span number 2 loading

$\sum Fy = 0$

$T_B + T_C = 14946{,}53$

$\sum MA = 0$

$Tc \,.\, 0{,}53 – 687{,}778 – 14946{,}53 \,.\, 0{,}265 + 708{,}261 = 7434{,}665$

$T_C = 7434{,}665$

$T_b = 7511{,}92$

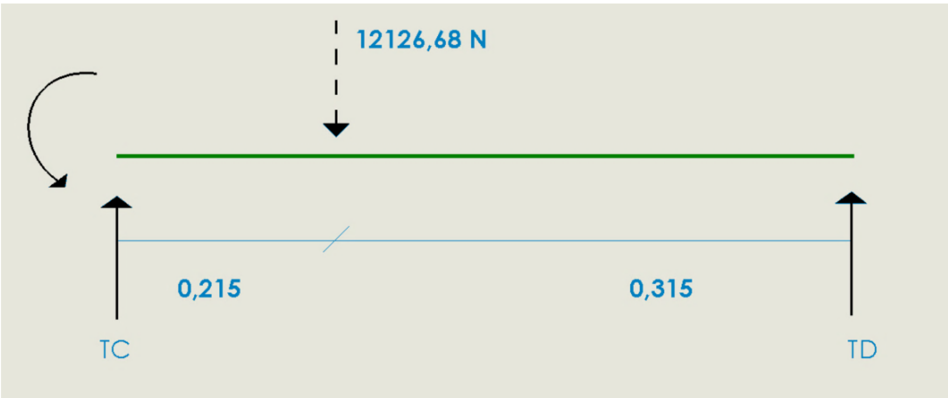

Figure 2.8: Span number 3 loading sheme

$T_C = 7207{,}36$

$T_D = 4919{,}32$

IV – Bending moment and shear force diagram (figure 2.9).

After determination of bending moment and total shear force in each support, diagram for these external forces has been ploted as following:

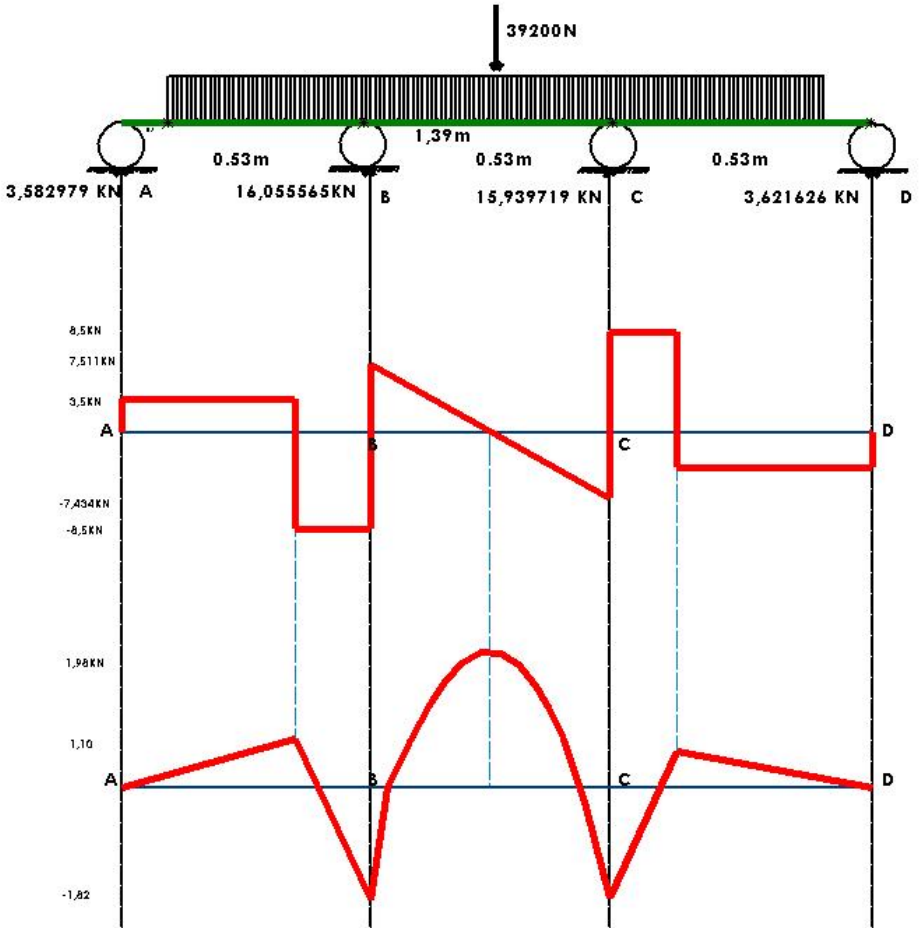

Figure 2.9 - Bending moment and shear force diagram

Determination of internal forces applied on middle span.

After analysing area under curve of shear force we have been able to find value of maximum bending moment. In the diagram where shear force is equel to zero we have maximum amount of bending moment. We cut our beam in span number 2 to find internal forces such as bending and shear stress.

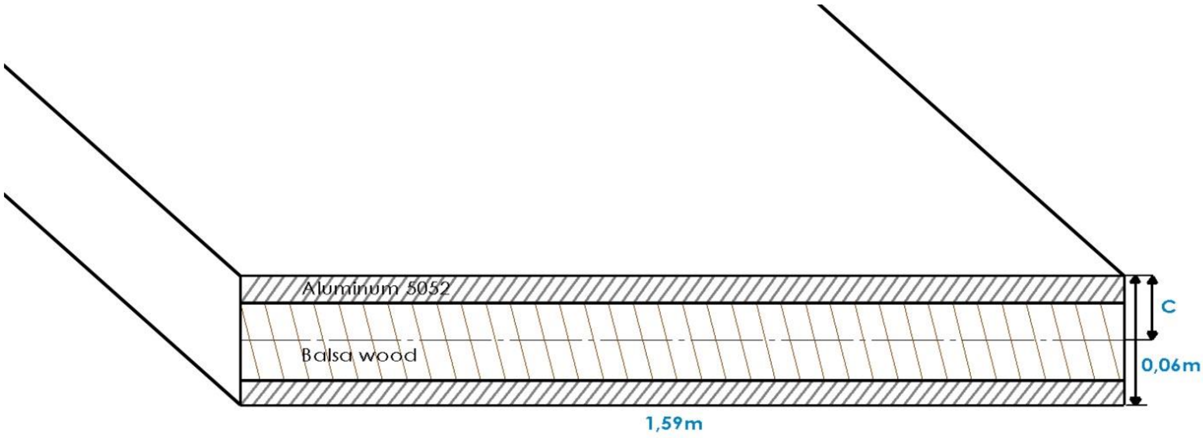

Figure 2.10 - Pallet's cross section

As we can see in diagram above our pallet consist of two different material. We have two layer of aluminium on the top and bottom of cross section and between these surfaces thre is Balsa wood as core. To calculate internal forces, moment of inertia for this cross section is require. Since the pallet consist of different materials and each material has its own strength properties, module of elasticity for each material is dissimilar from other section. For simplicity of calculation, first we need to find ratio between module of elasticity for both materials, subsequently we convert section with smaller thickness to part with bigger area. In this case we converted both layers of pallet that contains aluminium to all wood.

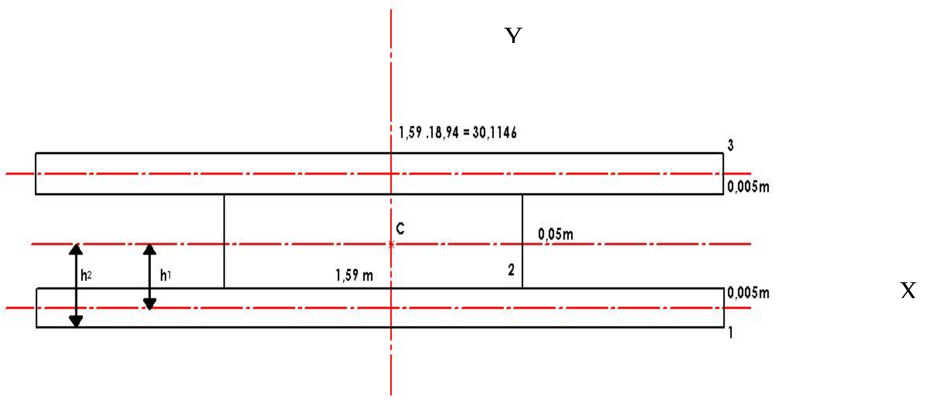

Figure 2.11 - Pallet's cross section converted aluminium part to all wood

Ratio between modules of elasticity of Aluminium and Balsa wood

$$n = \frac{Eal}{Ew} = \frac{70{,}3\ Gpa}{3{,}71 Gpa} = 18{,}94$$

Total moment of inertia of cross section

$I_{total} = I_{x1} + I_{x2} + I_{x3}$

$I_{x1} = IG_1 + A_1 h_1^2 = \frac{bd^3}{12} + bd\ .\ (0{,}0275)^2$

$I_{x1} = \frac{30{,}1146\ .\ 0{,}005^3}{12} + 30{,}1140\ .\ 0{,}005\ .\ (0{,}0275)^2 = 1{,}14.10^{-4}$

$I_{x2} = 1{,}65.10^{-5}$

$I_{x3} = 1{,}14\ .\ 10^{-4}$

$I_{total} = 2{,}44\ .\ 10^{-4}$

Calcultion of maximum normal and shear stress in Span 2:

$M_{max} = 2KN$

$(\sigma_{max}) = -\frac{Mmax.\ C}{I} = \frac{2\ .0{,}03}{2{,}44.10^{-4}} = -\ 245{,}90(\frac{KN}{m})$

$(\sigma_{max\,al}) = -245{,}90\ .\ 18{,}948 = -\ 4642\ (\frac{KN}{m})$

Max transverse shear for this cross section is $\tau_{max} = 0$.

Safety factor:

$(\sigma_{max\,al}) = 4642 \leq 19305$ allowable stress of (Al5052)

$\eta = \frac{\sigma_b}{\sigma_{max}} = \frac{19305}{4642} = 4{,}1$

Calcultion of maximum shear stress in Span 3:

$$\tau_{max} = \frac{T\,Q}{I\,t}$$

Q for span 3 = $\sum Ay$

$$Q = A_1 y_1 + A_2 y_2 = (30{,}1146.0{,}005).0{,}003 + (1{,}59.0{,}0025)0{,}0125 = 9{,}485.10^{-4}\ m^2$$

$$\tau_{\max} = \frac{8{,}5KN.9{,}485.10^{-4}}{2{,}44\,.10^{-4}.\ 1{,}59} = 200{,}7811\left(\frac{KN}{m^2}\right)$$

$$\tau_{\max al} = 200{,}7811\ .\ 18{,}949 = 3804{,}7810\left(\frac{KN}{m^2}\right)$$

$$\eta = \frac{\tau_b}{\tau_{\max}} = \frac{26684}{3804{,}7810} = 5{,}4$$

Conclusion to the part

For the conseptual pallet design, material and dimentions were considered of required pallet, then calculated external and internal forces, that applies to pallet when it places on 4 supports on cargo hold floor. Then I compared with allowabale stress of materials that they constructed from. And finaly, I have checked the strength of pallet under overload condition.

GENERAL CONCLUSIONS

According to information that achieved during work on diploma project and comparison of results that has been obtained based on calculations following results have been determined:

- at the first stage we compared different specifications of prototypes and chose Boeing C-17 which had most similar characteristics to our given data;
- processed preliminary design of middle range cargo aircraft with payload capacity of 76 ton, taking into account geometrical characteristic of airplane and safety requirements to calculate the basis of a successful and cost-effective plan for desire airlifter;
- calculated basic geometric parameters of appropriate landing gear for designed aircraft and selected proper type of tire capable of withstanding calculated transmitted loads on nose and main landing gear;
- introduced cargo compartment’s facilities for loading-unloading process as well as keeping cargo in safest manner during flight.

- center of gravity position of the equipment’s projected on aircraft based on their mass, moment and coordinates on mean aerodynamic chord , which has range between 18 to 23 %;
- selection and installation of turbo fan engine PW 2000 series of high-bypass turbofan aeroengines with a thrust range from 160 to 190 kN which has outstanding cruising speed and a good thrust to weight ration.
- conceptual pallet design, which first chose, material and dimensions of required pallet, then calculated external and internal forces that apply to pallet when it places on 4 supports on cargo hold floor, and then I compared with allowable stress of materials that they constructed from and finally checked the strength of pallet under overload condition.