МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
Кафедра конструкції літальних апаратів

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
д.т.н., проф.
____________Сергій ІГНАТОВИЧ
«___» __________ 2022 рік

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«АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА»

Тема: «Аванпроект середньомагістрального пасажирського літака місткістю до 250 пасажирів»

Виконала:	___________	**Ксенія МЕЛЕШКО**
Керівник: канд.техн.наук	___________	**Володимир КРАСНОПОЛЬСЬКИЙ**
Нормоконтролер: канд.техн.наук, доцент	___________	**Сергій ХИЖНЯК**

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MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
Department of Aircraft Design

PERMISSION TO DEFEND
Head of department
Dr.Sc., Professor
________ Sergiy IGNATOVYCH
«___» _________ __ 2022

BACHELOR DEGREE THESIS
ON SPECIALTY
"AVIATION AND AEROSPACE TECHNOLOGIES"

Topic: "Preliminary design of the mid-range passenger aircraft with up to 250 seats capacity"

Prepared by:	__________	**Kseniia MELESCHKO**
Supervisor: PhD	__________	**Volodymyr KRASNOPOLSKII**
Standard controller: PhD, associate professor	__________	**Sergiy KHYZHNYAK**

Kyiv 2022

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

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

ЗАТВЕРДЖУЮ
Завідувач кафедри, д.т.н., проф.
__________ Сергій ІГНАТОВИЧ
«___» __________ 2022 рік

ЗАВДАННЯ
на виконання дипломної роботи студентки

КСЕНІЇ МЕЛЕШКО

1. Тема роботи: «Аванпроект середньомагістрального пасажирського літака місткістю до 250 пасажирів», затверджена наказом ректора №489/ст від 10 травня 2022 року.

2. Термін виконання проекту: з 23 травня 2022 р. по 19 червня 2022 р.

3. Вихідні дані до роботи: максимальна кількість пасажирів 250, крейсерська швидкість 850 км/год, дальність польоту 5500 км, крейсерська висота польоту 10 км.

4. Зміст пояснювальної записки: вступ, основна частина, що включає аналіз літаків-прототипів і короткий опис проектованого літака, обґрунтування вихідних даних для розрахунку, розрахунок основних льотно-технічних та геометричних параметрів літака, компонування пасажирської кабіни, розрахунок центрування літака, спеціальна частина, яка містить проект балки підлоги для кріплення крісел.

5. Перелік обов’язкового графічного матеріалу: загальний вигляд літака (А1×1), компонувальне креслення фюзеляжу (А1×1), проект балки підлоги для кріплення крісел (А1×1).

6. Календарний план-графік:

№ пор	Завдання	Термін виконання	Відмітка про виконання
1	Вибір вихідних даних, аналіз льотно-технічних характеристик літаків-прототипів.	23.05.2022 – 26.05.2022	
2	Вибір та розрахунок параметрів проєктованого літака.	27.05.2022 – 30.05.2022	
3	Виконання компонування літака та розрахунок його центрування.	31.05.2022 – 03.06.2022	
4	Розробка креслень по основній частині дипломної роботу.	04.06.2022 – 06.06.2022	
5	Проектування балки підлоги для кріплення крісел та розробка креслень по спеціальній частині.	07.06.2022 – 11.06.2022	
6	Оформлення пояснювальної записки та графічної частини роботи.	12.06.2022 – 13.06.2022	
7	Захист дипломної роботи.	14.06.2022 – 19.06.2022	

7. Дата видачі завдання: 23 травня 2022 рік.

Керівник дипломної роботи ____________ Володимир КРАСНОПОЛЬСЬКИЙ

Завдання прийняв до виконання ____________ Ксенія МЕЛЕШКО

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty
Department of Aircraft Design
Academic degree "Bachelor"
Specialty 134 "Aviation and aerospace technologies"
Educational poffesional program "Aircraft equipment"

APPROVED BY
Head of the Department Dr.Sc., Professor
__________ Sergiy IGNATOVYCH
«___» _________ 2022

TASK
for the bachelor degree thesis

KSENIIA MELESCHKO

1. Topic: "Preliminary design of the mid-range passenger aircraft with up to 250 seats capacity" confirmed by Rector's order №489/ст 10.05.2022.

2. Thesis term: since 23.05.2022 till 19.06.2022.

3. Initial data: cruise speed 850 km/h, flight range 5500 km, operating altitude 10 km, 250 passengers.

4. Content (list of topics to be developed): introduction, main part: analysis of prototypes and brief description of designing aircraft, selection of initial data, wing geometry calculation and aircraft layout, landing gear design, engine selection, center of gravity calculation, special part: development and calculation of floore beam for passenger saets attachment.

5. Required material: general view of the airplane (A1×1), layout of the airplane (A1×1), floore beam design (A1×1).

6. Thesis schedule:

#	Task	Time limits	Done
1	Selection of initial data, analysis of flight technical characteristics of prototypes aircrafts.	23.05.2022 – 26.05.2022	
2	Selection and calculation of the aircraft designed parameters.	27.05.2022 – 30.05.2022	
3	Performing of aircraft layout and centering calculation.	31.05.2022 – 03.06.2022	
4	Development of drawings on the thesis main part.	04.06.2022 – 06.06.2022	
5	Design of the floor beam for attachment of passenger seats and making drawings on a special part.	07.06.2022 – 11.06.2022	
6	Formatting an explanatory note and a graphic part of the diploma work.	12.06.2022 – 13.06.2022	
7	Defense of the diploma work.	14.06.2022 – 19.06.2022	

7. Date: 23.05.2022.

Supervisor _____________ Volodymyr KRASNOPOLSKII

Student _____________ Kseniia MELESCHKO

РЕФЕРАТ

Дипломна робота «Аванпроект середньомагістрального пасажирського літака місткістю до 250 пасажирів» містить:

60 сторінок, 6 рисунків, 6 таблиць, 11 літературних посилань

В процесі написання роботи, було спроектовано та визначено основні льотно-технічні характеристики средньомагістрального пасажирського літака місткістю до 250 пасажирів. Для проектування літака, використовувався метод порівняльного аналізу літаків-прототипів для вибору найбільш обґрунтованих технічних рішень, а також метод інженерних розрахунків для отримання основних параметрів проектування літака. В спеціальній частині обґрунтовано застосування нової балки підлоги літака для кріплення пасажирських крісел, що має підвищену міцність порівняно з аналогами та меншу вартість. Для підтвердження характеристик міцності нової конструкції балки із застосуванням нового матеріалу проведено аналіз напружено-деформованого стану та показано її відповідність існуючим нормам.

Результати цієї роботи можуть бути використані в авіаційній галузі та в навчальному процесі авіаційних спеціальностей.

Пасижарський літак, аваніпроект літака, центрування літака, компанування пасажирської кабіни, розрахунок на міцність, аналіз напружено деформованого стану

ABSTRACT

Bachelor thesis "Preliminary design of the mid-range passenger aircraft with up to 250 seats capacity"

60 pages, 6 figures, 6 tables, 11 references

This thesis considers, the design of the mid-range passenger aircraft with a capacity of 250 passengers and determine it's main flight and technical characteristics. The design methodology is based on prototype analysis to select the most advanced technical decisions and engineering calculations to get the technical data of designed aircraft. In a special part, the new design of aircraft floor beam for passenger seats attachment have been developed, which has increased strength compared to analogues and lower cost. To confirm the strength characteristics of the new beam structure using a new material, the analysis of the stress-strain state was performed and meeting of with existing standards was proved.

The results of this work can be used in the aviation branch and in the educational process of aviation specialties.

Passenger aircraft, preliminary design, center of gravity calculation, passenger cabin layout, strength calculation, stress-strain analysis

Format	№	Designation	Name	Quantity	Notes
			<u>General documents</u>		
A4	1	NAU 22 02M 00 00 00 42 TW	Task for work	1	
	2	NAU 22 02M 00 00 00 42	Mid-range passenger aircraft	2	
A1		Sheet 1	General view		
A1		Sheet 2	Fuselage layout		
A4	3	NAU 22 02M 00 00 00 42 EN	Mid-range passenger aircraft	52	
			Explanatory note		
			<u>Documentation for assembly units</u>		
A1	4	NAU 22 02M 00 00 00 42	Design of floor beam	1	

			NAU 22.02M.00.00.00.42 EN			
Done by	Meleschko Kseniia	Preliminary design of mid-range passenger aircraft with 250 passenger capacity (List of diploma work)	list	sheet	sheets	
Supervisor	Krasnopolskii V.S.			9	52	
			ASF 402			
St.control.	Khyzhniak S.V.					
Head of dep.	Ignatovich S.R.					

CONTENT

INTRODUCTION

The aviation industry, like any other, is constantly evolving, while the emphasis was on the fastest possible to transport people to a specific place, now more important are the ideas of high fuel-efficient, engines with the lowest emissions, and research of various composite materials for greater strength at a lower weight. In the process of disegning this aircraft, the ecologicl espects was taken into account.

Most of the aircraft in my class are not made of environmentally friendly materials. Nowadays, most of the materials that harm the environment can be replaced with the same quality, sometimes cheaper and environmentally friendly materials. Composite materials are also ecology. This material often use in producing the tail of the aircraft, and the bow of the aircraft.

Therefore, takinf into acount all this, in designed plane was developed a new floor beam of composite materials. This will help reduce the weight of the aircraft and increase its environmental friendliness.

1. PROJECT PART. PRELIMINARY DESIGN OF MID-RANGE AIRCRAFT

1.1 Analysis of prototypes and short description of designed aircraft

The overall design of the aircraft is the process of determination and estimation of main flight performances of future aircraft to meet existing requirements and make it's general view. The designed aircraft is able to transport passengers and luggage over a distance of 5500 km with a maximum commercial load, with a cruising speed of 850 km/h, at an altitude of 10000 m .

The designed aircraft is a cantilever full-metal monoplane with a low sweepback wing. There are winglets at the ends of the wing, aimed to reduce induced drug and conventional tail unit configuration. The aircraft is equipped with two engines with a high bypass ratio and a tricycle landing gear with a nose support. The engines are installed under the wing. The prototype for the designed aircraft in this work are Tu-204. Statistic data of prototypes are presented in table 1.1.

Table 1.1

Performances of prototypes

Characteristics	TU-204	An-148-100	Designed plane
Crew, man	2	2	2
Maximum payload, m.max, kg	18000	11756	132325
Cruising speed, Vcr., km/h	880	820	850
Flight altitude, Hcr., m	11000	11000	10000
Flight range, L.max, km	3100	3100	5500
Specific load on the wing, kPa	5.55	4.20	4.568
Thrust-to-weight ratio, kN/kg	3	3.1	3.127
Take-off distance, Ltakeoff., m	2080	888	1748
Landing distance, Llandin., m	1300	645	1243
Take of speed Vdetcah., km/h	270	250	253
Landing speed Vland., km/h	230	219	228
Number and type of engines	2×Turbofan	2×Turbofan	2×Turbofan
Equivalent diameter of the fuselage, m	3.88	3.5	3.95
Fineness ratio	7.61	4.5	9.51
Sweepback angle on 1/4 chord,	35	23	25
Aspect ratio over the entire area	8.99	9.63	8.1

Taper ratio over the entire area	2.95	3	3.5
Average relative wing thickness	0.12	0.11	0.11
Span of horizontal tail, m	10.97	12.3	14.46
Taper ratio of horizontal tail	2.75	3	2
HTU aspect ratio	4.18	3.6	4
HTU area, m^2	-	22.45	35.49
Height of vertical tail, m	6.3	4.91	6.51
VTU area, m^2	-	16.33	24.20
Aspect ratio of vertical tail	1.2	1.2	1.2
Taper ratio of vertical tail	2	2	1.3
Ruder area, m^2	-	6.53	9.68
Landing gear base, m	18.92	11.62	13.15
Landing gear track, m	11.5	4.9	5.65

1.2. Brief description of the main parts of the aircraft

1.2.1. Wing

The wing consists of a centre section and two consoles. The joint of the centre section with the consoles is detachable. The wing centre section is attached to the reinforced frames of the fuselage by means of connecting nodes mounted on the side members of the centre section and on the frames of the fuselage. The joints of the wing with the fuselage are closed by braces. On the wing centre section, in the area of ribs, the engine nacelles are installed .

The design of the wing has a two-spar structure, made of aluminum alloys. The upper and lower panels of the aircraft wing kit are made of panel with pressed stringers riveted to them. The thickness of the coating is from 1 mm to 4 mm. Individual cladding panels can be made of thicker sheets 6-10 mm thickness by chemical etching and machining to obtain local reinforcements at the cross joints, mounting engine nacelles, flap supports, fuel system fittings and more. Maximum dimensions of the cladding sheets panel: width 1.2 m, length 9.3 m. Stringers up to 10 m long. Wing spars have a common beam structure, but ribs may be either beam or truss types. The center section of the wing is lockated at the airplane axis of symmetry and used as fuel tank [6].

For mounting engine nacelles, high-lift devices, control surfaces, etc. brackets, nodes and fittings are used in the wing design. In the structure of the root and tip parts of the wing can be used honeycomb structures with trimming of composite materials.

1.2.2. Fuselage

The design of the fuselage is semi-monocoque, consisting of three main sections: nose, middle and tail.

The crew cabin, passenger cabin are located in the sealed part of the fuselage. Over the wing on the starboard side of the fuselage there are emergency exits with size 510×910 mm, as well as on the starboard side in the tail is an emergency exit measuring 720×1380 mm. The front door is located in the tail of the fuselage on the larboard, with size 760×1700 mm. In the middle of the fuselage, the passenger cabin is located [4].

In the area of engines, the construction of the fuselage augmented in order to achieve acceptable levels of vibration and noise. On both sides of the lower part of the fuselage fairings are installed, which hide the fastening units of the main landing gear struts and wheels in the retracted position.

Tail unit fin spars are attached to the reinforced frames at the tail part of the fuselage.

The fuselage is made mainly of aluminum alloys. The design of the fuselage is developed taking into account the panel assembly and the widespread use of press rivets. The skin is made of aluminum alloys with additional reinforcement by frames in the area of door, hatch and windows. The skin and frames form a layered structure and are interconnected by gluing [4].

1.2.3. Tail unit

The type of aircraft and the location of the engines have a great importance for the choice of tail unit type. For the designed aircraft was used conventional tail unit in order to reduce weight and remove from the jet created by the engines [6].

1.2.4. Landing gear

The landing gear of the designed aircraft use wheels have tricycle type with a nose support. It has the next advantages:

- easier and safier landing;
- horizontal position of the aircraft axis on the groung, which improves the pilot's view, passenger’s comfort and loading of the cargo;

- good stability during take-off, run and taxiing at the aerodrome;
- the possibility of brakes applying immediately after touching the ground, which reduces the length of the run;
- possibility of bouncing is eliminated;
- possibility of nose-over is eliminated;

Disadvantages:

- grate mass due to high loads on the main supports;
- worst clearance;
- worst maneuverability;
- horizontal direction of jet stream during take-off;
- longer take-off distance due to absence of initiak angle of attack [4].

1.2.5. Control system

The entire flight process from take-off to landing is controlled by a fly-by-wire control system. The centralised control system including two independent systems with five computers. Two are used to control the elevator and ailerons, and three are used to control spoilers. The rudder is held by two flight stabilization computers, and the flaps are controlled by two specialized computers. On most aircraft centralised control is used because it increases flight safety and also significantly relieves the pilot. To increase the reliability of the fly-by-wire control system, two measures have been taken: signal cables leading to each control surface are separated from each other, for example, aileron and spoiler cables are laid before and after the front wing beam: to avoid lightning strikes; telex control cables are installed in metal shielding couplings, and their open parts are fixed in cable channels. This type of flight control system uses side stick instead of the usual control levers. This side handle control system reduces the weight of the entire system and includes a stick that tilts inward and forward, a block of tilt and step sensors, as well as a system of artificial feel devices. When using autopilot, a bayonet powered by an electromagnetic coil blocks the control system in the neutral position [4]. The electronic circuit is connected between two control units. Under normal circumstances, two pilots cannot fly an aircraft at the same time. To resolve the contradiction between the control input of the two pilots, a comparison device is built into the electronic circuit. The associated control can overlap with two input signals. If one pilot wants to cancel the other pilot's input, just hold the capture button to release the other pilot's manipulative input. Hydraulic systems differs by color: green, yellow and blue. The green and yellow systems are interconnected, and each one drives the engine. The blue hydraulic system is equipped with three motors, two of which are powered by conventional power motors, and the other motor – from the auxiliary power unit. It can also be used as an emergency power source in addition to ground use. In the event of a failure of all power sources, there is also an emergency 5000 VA motor powered by a blue hydraulic system, as well as a DC converter and a battery [5].

1.2.6. Onboard equipment

The integrated KISS information system uses multi-function liquid crystal displays to provide up-to-date information on engine parameters, parameters and condition of on-board systems, as well as faults in systems with recommendations for the crew to take the necessary measures. KISS also issues warning and alarm signals. At the same time, KISS collects information for the Multi-Channel Parameter Registration System (MRSP), which collects flight parameters and transmits the information to the Content Management System (CMS).

All flight settings, navigation and weather conditions are displayed on the screens of the electronic display system. Information on the screens can be published in both metric and imperial units [5].

Replacement flight equipment – speedometer, variometer, barometric altimeter, air horizon, radio magnetic display, magnetic compass.

The aircraft is automatically controlled by a computerized flight control system (FCS) and a computerized thrust control system (TCS).

Integrated Services Digital Network User Part (ISDN) or ISUP generates automatic aircraft control signals and command indicators of electronic scoreboards for direction control, as well as other information in related systems. ISUP generates signals for controlling thrust and movement of engine control levers depending on the aircraft configuration and flight parameters set by the crew or ISUP [5].

The onboard systems are interconnected via the widely used ARINC 429 interface, which simplifies equipment upgrades, including through the use of foreign-made components.

1.2.7. Choice and description of power plant

The aircraft is equipped with two turbofan engines type CFM56-5B. Engines are installed under the wing in nacelles on pylons. Engine suspension elements are the same for left and right engines. The engine is started from the air starter, or from the ground source, or from the second running engine. To the design features of these engines, which have a positive effect on operational and economic properties [1]. The data of these engines are presented in table 1.2.

Table 1.2.

Engines performances

Model	CFM56-2A-2	CFM56-2B1	CFM56-2C1
Thrust	24.000 lbf (110kN)	22,000 lbf (98 kN)	22,000 lbf (98 kN)
Bypass ratio	5.9	6.0	6.0
Overall pressure ratio	31.8	30.5	31.3
Dry weight	4,820 lb (2,190 kg)	4,671 lb (2,120 kg)	4,635 lb (2,100 kg)

1.3 Geometry calculations for the main parts of the aircraft

The layout of the aircraft is determined by the relative position of its parts and structures and requires consideration of all types of loads caused by passengers, cargo, fuel, etc. The choice of the scheme, composition and parameters of the aircraft is aimed to meet operational requirements at maximum.

1.3.1. Wing geometry calculation

Wing area is:

$$S_w = \frac{m_o \cdot g}{P_o} = \frac{75125 \cdot 9.81}{4568} = 161\ m^2.$$

where S_w – wing area, m^2; g – acceleration due to gravity m/s^2.

Wing span is:

$$l = \sqrt{S_w \cdot \lambda_w} = \sqrt{161 \cdot 8.1} = 36.15m,$$

where l – wing span, m; λ_w – wing aspect ratio

Root chord is:

$$b_o = \frac{2S_w \cdot \eta_w}{(1+\eta_w) \cdot l} = \frac{2 \cdot 161 \cdot 3.5}{(1+3.5) \cdot 36.15} = 6.94\ m,$$

where b_0 – root chord, m; η_w – wing taper ratio.

Tip chord is:

$$b_t = \frac{b_o}{\eta_w} = \frac{6.94}{3.5} = 1.98\ m,$$

where b_t – tip chord, m.

The relative position of the spars in the wing on the chord is equal to: $\overline{X} = \frac{X_i}{b}$, where X_i – distance i – first spar from the toe of the wing. For a wing with two spars $\overline{X}_1 = 0.2$, $\overline{X}_2 = 0.6$ This determines the width of the center section of the wing and the capacity of the fuel tanks [3].

Average relative wing thickness is:

$$\overline{C}\,av = 0.11.$$

On board chord for trapezoidal shaped wing is b_A:

$$b_A = \frac{4}{3} \cdot \frac{\eta_{кр}^2 + \eta_{кр} + 1}{(\eta_{кр} + 1)^2} \cdot \frac{S_{кр}}{l_{кр}} = \frac{4}{3} \cdot \frac{3.5 + 3.5 + 1}{(3.5 + 1)^2} \cdot \frac{161}{36.15} = 4.92\ m;$$

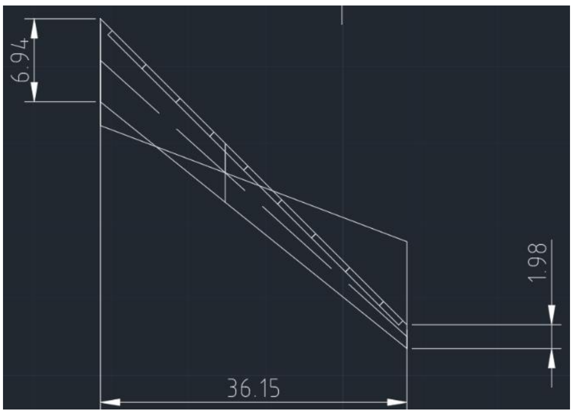

Figure 1.3. Determination of mean aerodynamic chord

1.3.2. Geometry parameters of the ailerons

Ailerons span is:

$$l_{ail} = 0.35\frac{l}{2} = 0.35 \cdot \frac{36.15}{2} = 6.33\ m,$$

where l_{ail} – ailerons span, m.

Ailerons area is:

$$S_{ail} = 0.06 \cdot \frac{S_{кр}}{2} = 0.06\frac{161}{2} = 5.24\ m^2,$$

where S_{ail} – ailerons area, m

Aerodynamic aileron compensation:

Axial is:

$$S_{axial.ail} = 0.25 \cdot S_{ail} = 0.25 \cdot 5.24 = 1.57$$

Internal is:

$$S_{internal} = 0.3 \cdot S_{ail} = 0.3 \cdot 5.24 = 1.57\ m^2$$

Aileron trimmer area is:

$$S_{TP} = 0.05 \cdot S_{ail} = 0.05 \cdot 5.24 = 0.37 m^2$$

Aileron deflection range is:

$$\text{up } \delta_{ail}^{'} = 25^{\circ}; \text{ down } \delta_{ail}^{''} = 15^{\circ}.$$

1.3.3. Fuselage layout

When choosing the shape and size of the cross section of the fuselage must take into account the requirements of aerodynamics. The most appropriate form of cross section is a round section, or a combination of several circles [3].

1.3.4. Determination of geometric and structural - force parameters of the fuselage

The length of the fuselage is chosen taking into account the features of the layout and alignment, as well as the conditions of the landing angle.

Fuselage length is equal to:

$$L_f = D_f \cdot \lambda_f = 3.95 \cdot 9.51 = 37.56\, m,$$

where D_f – fuselage diameter, m; l_f – length of fuselage nose part

Fuselage nose part fineness ratio is:

$$L_{n.p} = \lambda_{n.p} \cdot D_f = 1.5 \cdot 3.95 = 7.51\, m;$$

Fuselage rear part:

$$L_{r.p} = \lambda_{r.p} \cdot D_f = 2.5 \cdot 3.9 = 11.85\, m;$$

One of the main parameters that determine the model of the passenger cabin is the height of the passenger cabin. For mid-range aircraft, it is possible to assume approximately: cabin height $h_1 = 2\, m$; aisle width $b_{a.w} = 0.45\, m$; distance from the window to the floor $h_2 = 1\, m$; luggage space $h_3 = 0.8\, m$.

1.3.5. Layout of passenger and luggage equipment of the fuselage

Width of the chair: $b_{cor} = 460\, mm$.

Width of the armrest: $b_{flor} = 50\, mm$

Determinination the width of the cabin:

$$\text{B}_{cab} = m \cdot b_{cor} + K_1 \cdot b_{flor} + K_2 \cdot b_{pass},$$

where m – number of seats in a row; K_1 and K_2 – respectively, the number of armrests and aisles.

$$\text{B}_{cab} = 6 \cdot 450 + 8 \cdot 50 + 1 \cdot 450 = 3.55\, m$$

The length of the passenger cabin is:

$$l_{cab.eco} = 1200 + \left(\frac{n}{m} - 1\right) \cdot b_s + 250 = 1200 + 24.33 \cdot 800 + 250 = 19.68 \text{ m},$$

$$l_{cab.bis} = 1200 + \left(\frac{n}{m} - 1\right) \cdot b_s + 250 = 1200 + 2 \cdot 800 + 250 = 3.11 \text{ m},$$

where b_s – step chair.

We check compliance with the requirements for the volume per passenger

$$V_{\text{pass}} = V_{cab}/n \approx 0.9 \ldots 1\ m^3,$$

Where

$$V_{\text{cab}} = l_{\text{cab}} \frac{\pi(D_{\phi} - 0.24)^2}{4} = 21.6 \cdot \frac{3.14(3.95 - 0.24)^2}{4} = 233\ m^3;$$

When the flight lasts up to 2 hours. This layout can be considered satisfactory.

1.3.6 Luggage compartment

Luggage spaces are usually located in the airtight part of the fuselage under the cockpit floor [3].

The area of cargo compartment is defined:

$$S_{cargo} = \frac{m_{bag}}{0.4 \cdot K} + \frac{m_{cargo\&mail}}{0.6 \cdot K},$$

where m_{bag} i $m_{cargo\&mail}$– mass of luggage, mail and cargo, respectively, K= 500 kg/m^2 – specific load on the trunk floor.

$$M_{bag} = 170 \times 20 = 340\ kg$$

$$m_{cargo\&mail} = M_{comp} - (75 + 20) \times n,$$

where M_{comp} – mass of commercial load

$$M_{comp} = 20187\ kg$$

$$m_{cargo\&mail} = M_{comp} - (75 + 20) \times n = 20187 - 95 \times 170 = 4037\ kg$$

$$S_{cargo} = \frac{m_{bag}}{0.4 \cdot K} + \frac{m_{cargo\&mail}}{0.6 \cdot K} = \frac{360}{0.4 \cdot 500} + \frac{4275}{0.6 \cdot 500} = 16.05 \text{ m}^2;$$

Cargo compartment volume is equal to:

$$V_{cargo} = \bar{V}_{cr} \cdot n_{pass},$$

Where:

$\bar{V}_{cargo}$= 0.20…0.24 for fuselages d≤4 m;

$$V_{cr} = 0.23 \cdot 170 = 39.1\ m^3.$$

1.3.7. Galleys and buffets

Buffets and kitchens can not be placed close to toilets or combined with wardrobes.

Volume of buffets (galley) is equal to:

$$V_{galley} = 0.1 \cdot n_{pass} = 0.11 \cdot 170 = 18.7\ \text{m}^{3;}$$

Area of buffets (galley) is equal to:

$$S_{galley} = V_{galley}/h_{cab},$$

where h_{cab} – kitchen height.

$$S_{galley} = \frac{17}{2} = 9.35;$$

1.3.8. Wardrobes

Wardrobes for passengers' outerwear are located near the main doors for entry and exit of passengers. Wardrobes for crew clothes are made separate.

The area of the wardrobe is equal to:

$$S_w = 0.035 \cdot n_{pass} = 0.035 \cdot 170 = 8.5\ \text{m}^2;$$

The width of one row is equal to: 500 mm. Shoulder pitch: 80 mm.

1.3.8. Lavatories

The number of toilets is determined by the number of passengers during the flight, at t = 2…4 hours 1 toilet for 50 passengers, so we choose four toilets with an area of one toilet S_T=1.5 m^3 , with a width of at least one meter. The norms provide for a supply of water and chemicals in the toilets per passenger t=2…4 hour. Q = 1 kg.

1.3.9. Normal and emergency exits and emergency facilities

We accept 2 normal doors and 2 emergency exits.

The height of the door is equal to: $h_d = 1.8\ m$.

The width of the door is equal to:$b_d = 0.86\ m$.

All doors can be used as emergency.

1.3.10. Calculation of basic parameters and landing gear

Determine the removal of the main wheels of the landing gear:

$$e = 0.2 \times b_a = 0.2 \times 4.92 = 0.84\ m;$$

Determine the base of the landing gear:

$$B = k_b \times L_f = 0.4 \times 37.56 = 13.15\ m,$$

where B – wheel base, m; k_b – wheel base calculation coefficient

Front wheel axial offset will be equal to:

$$d_{ng} = B - e = 13.15 - 0.84 = 12.31\ m,$$

where d_{ng} – nose wheel axes offset, m

Wheel track is:

$$T = K \times B = 0.4 \times 13.15 = 5.65\ m,$$

where T – wheel track, m; k_T – wheel track calculation coefficient

To select the wheels of the landing gear determine the load on the wheels.

Main supports:

$$P_p = (B - \mathrm{e}) m_0 \cdot 9.81 / B \cdot n \cdot z;$$

where n and z – the number of supports and wheels on one support

$$P_p = (13.15 - 0.84) \times 75125 \times \frac{9.81}{13.15 \times 22} = 172518\ H,$$

Nose wheel load is equal to:

$$P_N = \frac{e \cdot m_0 \cdot 9.81 \cdot d}{B \cdot z} = \frac{0.84 \cdot 75125 \cdot 9.81 \cdot 1.5}{13.15 \cdot 2} = 35177\ H,$$

where K_d – coefficient of dynamism.

According the calculated values of wheel loading and take-off speed it is possible choose the tires for landing gear from the catalog:

for nose landing gear

Aircraft Rib 461B-3434-TL with parameters P_{rated}= 9000ibf size; V_{rated} =250MPH; size18×5.7-8.

for main landing gear

Aircraft Rib 461B-2728-TL with parameters, $P_{rated} = 12000\, lbf$; $V_{rated} = 195\, MPH$; size 22×7.75-10.

The rate of wheel loading is:

for nose wheel $\frac{9000-8835}{9000} \times 100\% = 1.83\%$;

for main wheel $\frac{12000-11593}{12000} \times 100\% = 3.39\%$

The values are less than 10% so choosed tires can be used for this airplane.

1.3.11. Determine the geometric parameters of the tail unit

We accept the areas of vertical and horizontal tail unit equal to:

$$S_H = (0.18\ldots0.25)S_{st};$$

$$S_H = 0.22 \cdot 161 = 35.49m^2;$$

$$S_V = (0.12.\ldots0.2) \cdot S_{st};$$

$$S_V = 0.2 \cdot 161 = 24.20m^2$$

Determine the area of the rudder height:

$$S_{RH} = (0.3\ldots0.4)S_H;$$

$$S_{RH} = 0.35 \cdot 35.49 = 10{,}65m^2;$$

Determine the area of the steering wheel directly:

$$S_{RH} = (0.35\ldots0.45)S_{VTU};$$

$$S_{RH} = 0.4 \cdot 24.2 = 9.68m^2;$$

Determine the area of the rudder trimmers height:

$$S_{rtm} = 0{,}1 \times S_{Pv};$$

$$S_{rtm} = 0.1 \cdot 10.65 = 1.06 m^2;$$

The area of the steering trimmers directly:

$$S_{rtm} = 0{,}05 \times S_{PH};$$

$$S_{rtm} = 0.05 \cdot 9.68 = 0.48 m^2;$$

We accept the scope of horizontal tail unit:

$$l_H = (0.32 \ldots 0.5) l_w;$$

$$l_H = 0.35 \cdot 36.15 = 14.46 m;$$

We accept the height of the vertical tail unit:

$$h_v = (0.14 \ldots 0.2).\, l_{st};$$

$$h_v = 0.15 \cdot 36.15 = 6.51 m;$$

Taper ratio of vertical and horizontal tail unit:

$$\eta_H = 2;$$

$$\eta_V = 1.3;$$

Aspect ratio of vertical and horizontal tail unit:

$$\lambda_V = 1.2;$$

$$\lambda_H = 4;$$

Chord of horizontal tail unit:

$$b_H = \frac{2 S_H}{(\eta_H + 1) l_H};$$

$$b_H = \frac{2 \cdot 35.49}{(2+1) 14.46} = 1.4 m;$$

Determine the root chord of the horizontal tail unit:

$$b_0 = b_K \cdot \eta_H;$$

$$b_0 = 1.4 \cdot 2 = 3.51\ m;$$

Determine the average aerodynamic chord of the horizontal tail unit:

$$b_H = 0.66\frac{4+2+1}{2+1}3.51 = 2.58\,m;$$

Chord of vertical tail unit:

$$b_V = \frac{2S_V}{(\eta_V+1)l_V};$$

$$b_V = \frac{2S_V}{(\eta_V+1)l_V} = \frac{2\cdot 24.2}{(1.3+1)\cdot 6.51} = 2.48\,m;$$

Determine the root chord of the vertical tail unit:

$$b_0 = b_H \cdot \eta_V = 2.48 \cdot 1.3 = 4.96\,m;$$

Determine the average aerodynamic chord of vertical tail unit:

$$b_V = 0.66 \cdot \frac{\eta_{OV}^2+\eta_V+1}{\eta_V+1} b_V = 0.66 \cdot \frac{1.3^2+1.3+1}{1.3+1} \cdot 4.96 = 3.82\,m.$$

Relative profile thickness for horizontal and vertical in the first approximation:

$$\bar{C}_{on} = 0{,}08.$$

1.4. Centre of gravity calculation

The final layout and centering of the aircraft is the only inseparable process. To ensure the required degree of static stability and controllability of the aircraft, its centering must be in a certain range along the length of the MAC. During the operation of the aircraft, the position of its centering may change: in this particular flight – as fuel is used, as well as due to differences in the options for loading the aircraft. The rear alignment must be as close as possible to ensure the minimum required limit of static stability of the aircraft. The maximum allowable front centering of the aircraft is determined by the efficiency of its longitudinal controls (balancing). The greater the efficiency of the longitudinal controls, the more acceptable the front centering of the aircraft and the wider, so it will be acceptable range of its operational centering.

1.4.1. Determination of the center of mass of the equipped wing

The mass of the equipped wing includes the mass of its structure, the mass of the equipment placed in the wing and the mass of fuel. Regardless of the mounting location (to the wing or to the fuselage), the main landing gear supports as well as the front landing gear support are included in the weight list of the equipped wing. Positive values of the coordinates of the centers of gravity of objects are taken towards the tail [2].

The coordinates of the centeringof the equipped wing is determined by the formula:

$$X_k = \frac{\sum m_i X_i}{\sum m_i}$$

where X_k – center of mass for equipped wing, m; m_i – mass of a unit, kg; x_i – center of mass of the unit, m.

Table 1.3

Centering sheet of the mass of the equipped wing

Name	Relative mass, %	Mass, kg	Coordinates, m	Moment of mass, kgm
Wing (structure)	0.08952	11849.58	2.07	24528.64
Fuel system	0.094	12442.59	2.19	27249.28
Aircraft control 30%	0.025	3309.2	2.95	9762.14
Electrical equipment	0.03	3971.04	0.49	1945.81
Anti-icing system 70%	0.0118	1561.942	0.49	765.3518
Hydraulic system 70%	0.0152	2011.994	2.95	5935.381
Equipped wing without fuel	0.26552	35146.35	1.89	66426.6
Fuel	0.3	39710.4	2.19	86965.78
Front landing gear support 30%	0.012	1588.416	-10.81	-17170.8
Main landing gear support	0.011	1456.048	2.34	3407.152
Total	0.58852	77901.22	1.65	128537

1.4.2. Determination of the centering of equipped fuselage.

Origin of the coordinates is chosen in the projection of the nose of the fuselage on the horizontal axis. For the X axis take the structural axis of the fuselage [2] .

Table 1.4

Centering of the equipped fuselage

N	Object name	Mass is relative, %	Mass, kg	Coordinates, m	Moment of mass, kgm
1	Fuselage	0.09325	12343.32	17.66	217983
2	HTU	0.08	10589.44	35.45	375395.6
3	VTU	0.076	10059.97	33.87	340731.1
5	Dashboard	0.0039	516.2352	3.11	1605.491
6	Aeronavigatiton equipment	0.0055	728.024	1.12	815.3869
7	Power plant	0.00302	399.7514	16.12	6443.992
8	Radio equipment	0.0021	277.9728	2.52	700.4915
9	Toilet	0.0016	211.7888	19.7	4172.239
10	Wardrobe equipment	0.0034	450.0512	19.7	8866.009
11	Galley	0.0104	1376.627	7.3	10049.38
12	Cargo equipment	0.0046	608.8928	15.78	9608.328
13	Aircraft control	0.0052	688.3136	18.78	12926.53
14	Electrical equipment	0.03	3971.04	18.78	74576.13
15	Hydraulic system	0.00152	201.1994	22.54	4535.034
16	Decorative cladding	0.0074	979.5232	18.78	18395.45
17	Chemical liquid	0.005	661.84	19.7	13038.25
18	Anti-icing system	0.00288	381.2198	26.3	10026.08
19	Passenger seats	0.03	3971.04	17.67	70168.28
20	Emergency rescue equipment	0.0113	1495.758	17.67	26430,05
21	Crew seats	0.0017	225.0256	4.85	1091.374
	Equipped fuselage without commercial load	0.37877	50137.03	18.24	914499.4
22	Passengers	0.01351	1788.292	17.67	31599.11
23	Luggage	0.0132	1747.258	15.78	27571.72
25	Crew	0.006	794.208	4.85	3851.909
24	Equipped fuselage	0.41148	54466.78	17.52	954258.1

1.4.3. Determine the coordinates of the centering of the equipped fuselage:

$$X_f = \frac{\sum m_i' \cdot X_i'}{\sum m_i'};$$

The position of MAC leading edge relative to fuselage nose may be calculated by formula.

$$X_{MAC} = \frac{m_f \cdot X_f + m_w \cdot X_w^{'} - m_0 \cdot C}{m_0 - m_w} = 15.87 \text{ m}.$$

Table 1.5

Centering of the equipped fuselage

Name	Mass, kg	Coordinates, m	Moment of mass, kgm
Equipped wing without fuel	35146.35	17.76	624199.2
Landing gear front support (retracted)	1588.416	5.06	8037.385
Main landing gear support (retracted)	1456.048	18.21	26514.63
Fuel	35146.35	18.06	634743.1
Equipped fuselage without commercial load	50137.03	18.24	914499.4
Passengers	1788.292	17.67	31599.12
Luggage	1747.258	15.78	27571.73
Crew	794.208	4.85	3851.909
Main landing gear support (extended)	1588.416	18.21	28925.06
Front landing gear support (extended)	1456.048	3.86	5620.345
Fuel at landing	2616	18.06	47245.68

1.4.4. Calculation of center of gravity positioning variants

Table 1.6

Airplanes C.G position variants

№	Download options	Mass, kg	Moment of mass, kgm	Center of mass, m	Centering, %
1	Main take-off, (landing gear retracted)	132368	2319087.36	17.52	28.52
2	Main take-off, (landing gear retracted)	132368	2317763.68	17.51	27.26
3	Landing (landing gear extended)	67276.88	1174654.32	17.46	28.24
4	Distillation (landing gear extended)	53259.86	945879.84	17.76	35.47
5	Parking (empty equipped)	42345.70	755870.745	17.85	35.24

Conclusions to project part

In the poject part was designed the new airplane with the next results:

- Sketch design of a mid-range aircraft for 250 passengers;

- Layout of the cabin of a medium-haul aircraft for 250 passengers;

- Calculations of the center of gravity of the aircraft;

- Calculations of the basic geometric parameters of the landing gear;

- Selection of wheels that meet the requirements.

Designed aircraft satisfies the planned aim of usage, its geometrical characteristics will provide the necessary aerodynamic performance, which will lead to efficient usage.

2. SPECIAL PART. THE FLOOR BEAM

2.1. Introduction

Beams used in the aircraft structures must meet the specified requirements of strength and stiffness with the smallest mass. In the design of an aircraft, beams sustain bending with shear and compression (or tension) at the same time. Therefore, the shape of the beam section should be chosen so that the largest part of the material is located as far as possible from the neutral axis [9].

We are considering 2 longitudinal beams, which are the load-bearing element of the cabin floor. They are located along the axis of the aircraft between frames No. 1 and 5. Beams are usually made of duralumin, equally strong, with U-shaped section 2 mm thick. Beam width – 210 mm, height in the middle – 75 mm and at the ends – 40 mm. From below, the beam is protected by a metal sheet of 0.6 mm thick. The ends of the beams are riveted to the cross-section of frames No. 1 and 5 by brackets. The upper plane of the beams, together with the sheets, forms the floor of the cockpit, divided into two parts by a passage.

The horizontal passage panel is located along the threshold of frame No. 5 and has a rigid stamped frame below, riveted with a smooth sheet. The panel is laid on beams of frames No. 2, 3 and 4 and riveted to them, forming a step 360 mm high from the floor of the cargo compartment. To provide convenient access to units located under the floor, the middle part of the floor in the cockpit between frames No. 4 and 5 is easily removable [9].

Removable side panels are mounted on screws along the passage, which, when removed, provides convenient access from the cab to the installation sites of the units located under the floor. Ahead of the passage is an easily removable casing that covers the aircraft control system elements.

To unload the upper fuselage beams in the front of the cabin, a stiffening element is installed, made of a sheet with thickness 1.5 mm. The stiffening element is riveted to the spars and frame No. 1 and simultaneously serves as a panel for installing equipment.

The frame of the passenger or cargo compartment fuselage floor (Fig. 2.1) consists of longitudinal and transverse beams and serves to fasten the floor panels. The transverse beams are structural elements of the middle part fuselage frames, which are described above [4].

The longitudinal set of the floor consists of longitudinal beams, diaphragms and walls. The longitudinal beams are installed in seven rows at a distance of 250 mm between the rows. Beams – channel section, made of a metal sheet 2 mm thick and fixed on the horizontal shelf of the frame with two countersunk rivets. Between frames No. 5 and 7, the profiles are installed in the transverse direction.

The diaphragms are located along the axis of the aircraft and at the sides. They consist of a 0.8 mm thick web with edges and holes for lightening, riveted with pressed corners. The diaphragms are attached to the vertical posts and horizontal caps of the frame with the help of rivet-knits. Part of the brackets has stamped holes and springs for screw locks, which are attached to the frame of the floor panel. The diaphragms located at the sides are connected to the frames with additional sheets. The sheets have a side to which the inner lining is attached with screws.

The walls are located along the axis of the aircraft between frames No. 5 and 7 and at the sides of the fuselage between frames No. 8 and 9. The walls are made of a sheet 1 mm thick, reinforced with pressed elements, and riveted with their lower side to the fuselage skin. In the side walls there are holes for the passage of flap control rods.

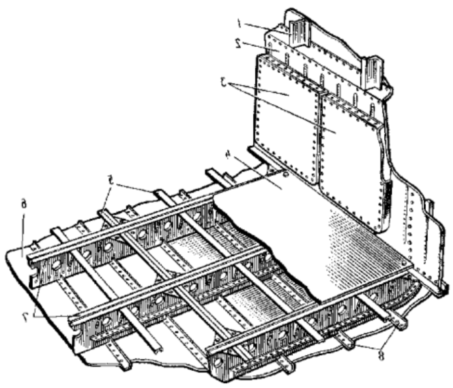

Fig. 2.1. Cargo floor frame:

1 – frame; 2 – side panel; 3 – folding hard seats; 4 – floor panel; 5 – longitudinal beams of the floor; 6 – duralumin sheathing; 7 – frames; 8 – stringer.

The flooring consists of separate panels that are laid on the frame and each of them is attached to it with four spring locks. The panel consists of a sheet of plywood 4 mm thick, lined on both sides with duralumin sheets 0.5 mm thick. Duralumin sheets are glued to plywood with BF-2 bakelite glue and riveted along the contour with rivets. The panel on the outside is covered with cork chips on AK-20 nitroglue to prevent feet from slipping when moving around the cabin [8].

The floor structure is designed for a load of 1000 kgf/m^2. Between frames No. 8 and 9 there is a hatch for access from the cockpit to the electromechanism UZ-1AM for controlling the lower flaps, which is closed by a panel.

To secure cargo on the sides of the fuselage, nine mooring brackets are installed (five below and four above the passenger seats) and 13 steel knots with rings that are screwed into nests riveted into the floor frame elements. The side brackets are made of АЛ4 alloy and are bolted and riveted to the fuselage frames.

Steel knots are an eye bolt with a thread and a ring. The removed mooring rings are stored in a special box cut into the floor panel at frame No. 15, and their sockets are closed with plugs.

To secure cargo to the aircraft, nine mooring cables and a net are applied. On the right side of the fuselage inside the cargo compartment, marks and inscriptions of the location of the cargo are applied [8].

A floor is installed along the tail compartment, consisting of separate panels, laid on U-shaped elements. The panels are similar to those of the cargo compartment and are attached to the fuselage structural elements with spring locks.

The flooring of the tail compartment floor between the frames was replaced by a light metal track covered with cork chips. The panels are attached to the frames with bolts and anchor nuts.

2.2. Advantage of new floor beam

The proposed improvement of floor structure belongs to the field of structural elements of the main air frames of the aircraft, directly to the support beams of the bottom of the sealed fuselage. The task is to develop a carrier design that will be lighter in weight and easier to integrate into the aircraft design. In addition, the design of the beam must allow the passage of cables and other communications without compromising its strength. This goal is achieved by the fact that the floor beam of the aircraft, containing cross spiral rods and interconnected, is made in the form of a hollow mesh structure, which in cross section has the shape of a rectangular frame with rounded corners. In addition, the spiral ribs are made in the beam in the form of anti-twist spirals with rectangular turns that intersect and fasten to each other, connected at the ends of the monolithic sections of the polymer fabric composite material [7].

An aircraft floor beam (Fig 2.2.) made of polymer composite materials according to claims 1 and 2, characterized in tat it is additionally provided with longitudinal and transverse ribs associated with spiral ribs. Moreover, the beam is additionally provided with longitudinal ribs connected to the helical ribs.

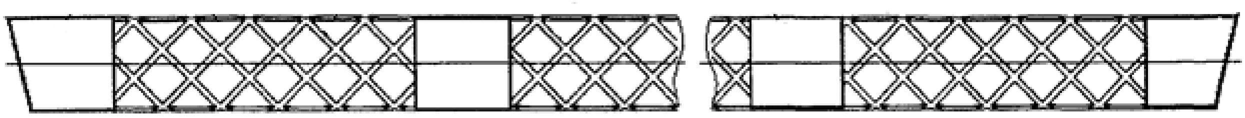

Fig 2.2. Aircraft floor beam made of polymer composite materials.

Also, the design of the floor beam, in contrast to the known ones, is made in the form of a closed mesh structure with a round constant cross-section along the entire length of the part, as a result of which there is a plane on each side of the floor beam, which allows attaching the parts to be attached to it with simple fasteners. All intersecting planes of the floor beam have mating radii to prevent sharp bends of the reinforcing fibers of the filler in these places, which reduce their strength [11].

In addition, in the places of future installation of attached parts, in the mesh frame of the floor beam, in contrast to the known ones, there are monolithic sections based on woven fibrous filler, which represent local reinforcement of the floor beam at the attachment points of the attached parts.

These monolithic sections distribute the concentrated loads from the attached parts to the group of ribs with which they intersect, and also allow the attached parts to be attached to it in the least laborious and most structurally simple way, which increases the productivity of fastener manufacturing and the productivity of assembly operations.

The floor beam (Fig. 2.3) is made in the form of a hollow mesh structure having a cross-sectional shape of a round frame with rounded corners. The beam includes spiral ribs made in the form of spirals of opposite twist with round turns, intersecting and fastened together. In addition, the beam has monolithic sections of polymer composite materials (PCM) based on woven filler associated with spiral ribs. At the same time, monolithic sections serve to connect the ends of the spiral ribs and for attachment with the fuselage structure. Monolithic sections are designed for joining the beam with floor elements. The beam is made with longitudinal ribs extending on the upper and lower surfaces. All ribs have a rectangular section and a unidirectional structure, since all the fibers reinforcing them are directed along the axis of the ribs. The location of the transverse and longitudinal ribs is chosen so that each rib in the intersection zone intersects with only one other rib [7].

The angle of intersection of the spiral ribs is 45 ± 5 degrees to the longitudinal axis of the beam, because this angle is optimal when the floor beam is loaded with torques, and torque loads are present during all changes in the aircraft flight mode, including take-off and landing. The transverse ribs are located at an angle of 90° to the mandrel axis, and the longitudinal ribs are parallel to the part axis. Moreover, for technological reasons, the longitudinal ribs are arranged in pairs and symmetrically on opposite flat parts of the floor beam.

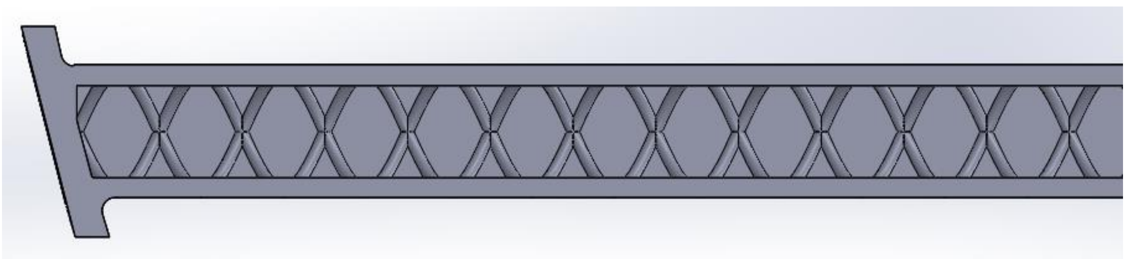

Fig. 2.3. Beam cross-section.

Longitudinal ribs and monolithic sections both have a closed shape and repeat the cross section of the floor beam. That is, they have the shape of a rectangle with mating radii. Longitudinal ribs have different widths from spiral ribs. The number of longitudinal ribs in a particular floor beam design is determined by the loads acting on it. For some floor beams, the operational loads are such that transverse and longitudinal ribs are not required. In this beam, two longitudinal ribs are used, which fully cope with the loads that act on the beam [7].

All helical fins have the same thickness. The longitudinal ribs also have the same thickness as the spiral ribs. The same thickness is achieved by varying the width of the ribs, because strength calculation optimizes the required cross section of longitudinal and transverse ribs and, given their thickness, their width is determined.

The floor beam has a layered structure, because its formation is carried out by layers of fibrous filler impregnated with a polymer binder, which is called a prepreg. The ribs are wound with a prepreg in which all the fibers of the filler are parallel and directed along its length, such a prepreg is called unidirectional. Monolithic sections are wound, including fabric-based prepreg and it is called woven prepreg.

Layer structure of one of the unidirectional ribs, incl. at the places where they intersect with two other unidirectional ribs, where the layers of one rib alternate with the layers of other ribs crossing it, forming a single design of parts.

Where the ribs intersect, there are more layers and less resin, and where the ribs intersect, there are fewer layers, which are compensated by the higher resin content.

In places of monolithic sections, after the formation of each first layer of all ribs, the first layer of woven prepreg is laid with a width of a monolithic section. Further, everything is also repeated in layers until the required thickness of the part is formed. As a result, there is a sequential alternation of layers of woven and unidirectional prepregs at their intersections according to a scheme similar to the scheme in Fig. 5, and in places where there are no ribs, PCM is formed with a woven filler and with a relatively high content of polymer resin, as these places contain fewer layers.

A floor beam made of polymer composite materials is wound on a winding machine onto a special mandrel with a layer-by-layer unidirectional prepreg tape for ribs and a woven prepreg tape for monolithic sections, as follows [7].

First, sequential winding of the first layers of all ribs is carried out in any sequence. Moreover, the chosen sequence on the first layer must also be observed when winding the remaining layers of ribs. For definiteness, we choose the following winding sequence: spiral ribs, transverse ribs, longitudinal ribs.

After winding the first layer of helical ribs, the first layer of longitudinal ribs is wound, and then the first layer of transverse ribs. After that, in places of monolithic sections, one layer of woven prepreg is wound.

The formation of the first layer of helical ribs takes place over several revolutions of the winding machine until the first layers of all helical ribs are formed.

Usually, the formation of one layer of helical fins requires winding with a lead of two or more, depending on the frequency of the helical fins. In this case, intersections of ribs with reinforcement angles of +45° and -45° are formed. Upon completion of the formation of the first layer of spiral ribs, the prepreg tape is cut off and the winding of the transverse ribs is started.

The first layer of the first transverse rib is formed in one turn of the mandrel, after which the prepreg strip is cut and the first layer of the next transverse rib is also formed, and so on until the completion of the formation of the first layers of all transverse ribs.

The first layers of longitudinal ribs are wound in pairs. The winding of the first layer starts from the zone of one of the technological allowances, the winding of the layer of the longitudinal rib is continued in the zone of the part until the prepreg tape enters the zone of the technological allowance from the opposite side of the mandrel. Here, the prepreg tape is wrapped around the mandrel and returned to the part area at the bottom of the mandrel. Further, the winding of the lower rib symmetrically located to the first longitudinal rib continues until it enters the technological allowance zone, from where the winding of the layer of the longitudinal rib began. Here the prepreg tape is cut. The place of beginning and end of winding of the layer of the first pair of the first layer of longitudinal ribs is marked with a line. The next pair of longitudinal ribs is wound in the same way until the winding of all first layers of longitudinal ribs is completed.

Then the first layers of monolithic sections are wound with a woven prepreg. The scheme of their formation is similar to the scheme of formation of transverse ribs. The difference is that the woven prepreg tape coincides with the width of the monolithic section and when it is wound, the woven prepreg intersects not only with all the ribs in this zone, but also with the weaves of these ribs. Therefore, in these places in the floor beam there will be the largest number of layers and the lowest content of the binder due to its squeezing into places with a smaller number of layers during the subsequent curing operation of the part.

The smallest number of layers is formed in places where there are no ribs, where a composite material is formed only on the basis of a woven filler, which is compensated by a high content of a polymer binder in it [10].

Further, everything is also repeated in layers, i.e. on the first layers of spiral, transverse, longitudinal ribs and monolithic sections, the second layers of spiral, transverse, longitudinal ribs and monolithic sections, respectively, are sequentially laid, then the third, fourth layers, etc. until the specified thickness of the part is formed.

The sections of the floor beam between the ribs and the monolithic sections remain unfilled with material and through holes are formed there. After the winding of the part blank is completed, it goes through the molding operation in an oven or autoclave under the influence of the temperature, pressure and holding time required by the technological process until the binder is cured.

Thus, a mesh structure is obtained, in which all the ribs and monolithic sections, after the completion of the curing and machining operation to separate the technological allowance, form a single structure of the floor beam [11].

This design implements the main advantages of PCM – almost all elements of the floor beam – unidirectional ribs, work along the reinforcing fibers, except for monolithic sections in places where woven reinforcing fillers are located. Moreover, monolithic sections with woven reinforcing fillers redistribute concentrated loads from the attached elements to unidirectional ribs. Such a design is much lighter than both metal analogues and an I-beam of a PCM floor. In addition, the design reduces labor costs for the manufacture of floor beams by eliminating the operation of forming cover layers and eliminating the operation of machining to create through holes, reduces labor costs for the manufacture of fasteners by simplifying the design of assembly structures. Such simplifications make it possible to realize the presence of flat surfaces on the shell and the presence of monolithic sections. Monolithic sections based on woven fillers make it possible to distribute concentrated loads from fasteners in a structurally simple way attached parts to a sufficient number of ribs without causing their overload. Also, the complexity of assembling the floor beam with the parts attached to it is reduced, because fasteners have a much simpler design. For the same reasons, labor productivity in assembly operations increases. Due to the use of plastic woven reinforcements on monolithic sections in this technical solution, it is enough to drill mounting holes in them in these places and install simple structural fastener details, for example, a bolt with a nut. This further simplifies the design of fasteners and reduces the complexity of assembly even more [7].

2.3. Calculation of beam

The most important thing in the design and calculation of a beam is the actual forces and deformations that can occur. Thanks to the calculation of strength, when the forces will actually act we can state that beam is strong enough.

At the beginning, we design the beam and apply all the forces that act on it (Fig. 2.4).

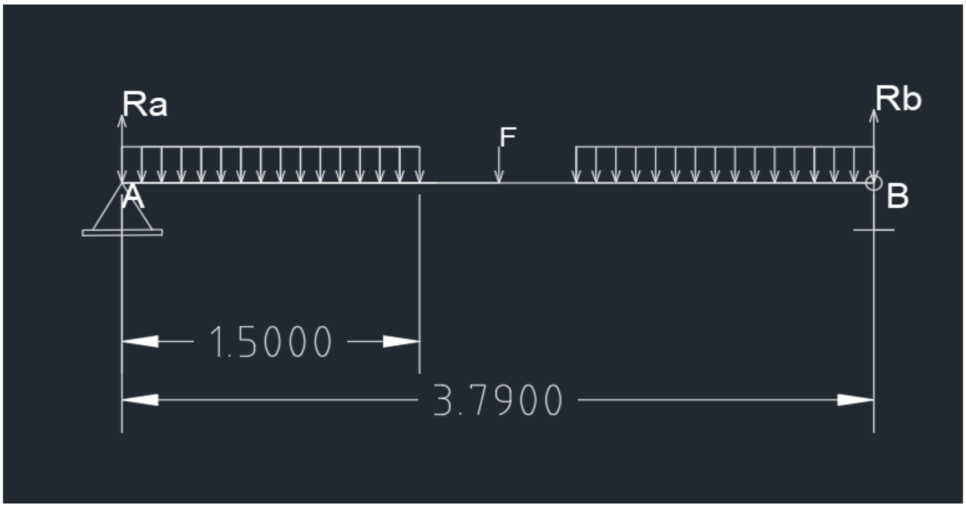

Figure 2.4. Beam calculation scheme.

Next, we need to write down the data that we need: $L = 3.8m, a = 1.5m, F = 4000\ H, q = 10800\ H\backslash m.$

1. Determin the reaction:

$$\sum M_a: -q_a - F\frac{l}{2} - q_a\left(l - \frac{a}{2}\right) + R_b l = 0$$

$$R_b = \left(q\frac{a^2}{2} + \frac{1}{2}Fl + q_a l - q\frac{a^2}{2}\right)\frac{1}{l} = \frac{1}{2}F + q_a$$

$$\sum M_b: -R_a l + q_a\left(l - \frac{a}{2}\right) + F\frac{l}{2} + q_a\frac{a}{2} = 0$$

$$R_a = \left(q_a l - \frac{q_a^2}{2} + \frac{Fl}{2} + \frac{q_a^2}{2}\right)\frac{1}{l} = \frac{1}{2}F + q_a$$

$$R_a = R_b = \frac{1}{2} \times 4000 + 10800 \times 1.5 = 2000 + 16200 = 18200\,H$$

2. Determine Q and M in any section:

1) $Q = R_a - qx;$ $M = R_a x - q_a\frac{x}{2}$

$$X_1 = 0; \quad Q = R_a; \quad M = 0;$$

$$X_1 = 0; \quad Q = 18200H; \quad M = 0\,H$$

$$X_2 = a \quad Q = R_a - q_a \quad M = R_a a - q\frac{a^2}{2}$$

$$X_2 = 1.5 \quad Q = 2000 \quad M = \frac{4000\times 1.5}{2} + \frac{10800\times 1.5^2}{2} = 3000 + 12150 = 15150H$$

2) $Q = R_a - q_a;$ $M = R_a x - qa(x - \frac{a}{2});$

$$X_2 = a; \quad Q = R_a - q_a; \quad M = R_a a - qa(x - \frac{a}{2});$$

$X_2 = 1.5; \quad Q = 2000H \quad M = 18200 \times 1.5 - 10800\left(1.5 \times \frac{1.5}{2}\right) = 27300 - 12150 = 15150$ H

$$X_3 = \frac{l}{2}; \quad Q = R_a - q_a; \quad M = R_a x - qa(x - \frac{a}{2});$$

$$X_3 = 1.9; \quad Q = 2000\,H; \quad M = 18200 \times 1.9 - 10800\left(1.5 \times \frac{1.5}{2}\right) = 34580 - 18630 = 15950\,H$$

3) $Q = R_a - qa - F;$ $M = R_a x - qa\left(x - \frac{a}{2}\right) - F(x - \frac{l}{2})$

$$X_3 = \frac{l}{2}; \quad Q = R_a - qa - F; \quad M = R_a x - qa\left(x - \frac{a}{2}\right) - F\left(x - \frac{l}{2}\right);$$

$$X_3 = 1.9; \quad Q = 200 - 400 = -2000\,H;$$

$$M = 18200 \times 1.9 - 10800 \times 1.5(1.9 - 0.75) = 15950\,H$$

$$X_4 = l - a;\ Q = R\_a - qa - F; \quad M = R\_a\,x - qa(x - a/2) - F(x - l/2);$$

$$X_4 = 2.3; \quad Q = -2000\,H$$

$$M = 18200 \times 2.3 - 10800 \times 1.5(2.3 - 0.75) - 4000 \times 0.4 = 15150\,H$$

4) $\quad Q = R_b + qx; \qquad M = R_b x + q_a \frac{x}{2}$

$$X_1 = 0; \quad Q = R_a; \quad M = 0;$$

$$X_1 = 0; \quad Q = -2000H;\ \ M = 0\,H$$

$$X_2 = a \quad Q = R_a - q_a \quad M = R_a a - q\frac{a^2}{2}$$

$$X_2 = 1.5 \quad Q = -18200 \quad M = \frac{4000 \times 1.5}{2} + \frac{10800 \times 1.5^2}{2} = 3000 + 12150$$

$$= 15150H$$

Results of calculation you can see on Fig 2.5

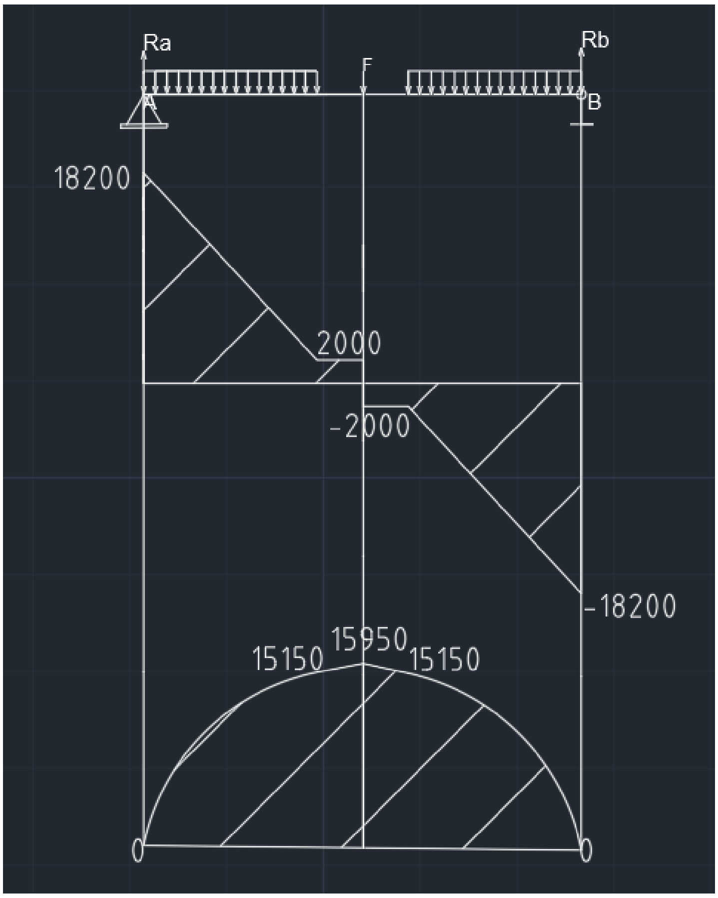

Fig. 2.5. Results of strength calculation.

Conclusion to the special part

The floor beam according to this design allows:

- reduce the weight of the structure by at least 40%;

- reduce the labor intensity of its manufacture by eliminating the operation of forming the outer cover layers and eliminating the operation of machining these layers to create through holes for air, electrical and hydraulic lines;

- to simplify the design of the fastener parts of the attached elements and thereby reduce the complexity of their manufacture due to the presence of flat surfaces and woven monolithic reinforcements;

- the absence of woven reinforcements requires the use of a complex fastening design of the attached parts to ensure their support on several ribs, while the woven reinforcement provides transmission loads from attached parts on several ribs, because is included in their structure;

- reduce the complexity of assembling the floor beam with attached parts by simplifying the design of fasteners for flat surfaces of the part;

- increase the reliability and reduce the complexity of assembling a floor beam with mating parts due to the presence of monolithic sections based on woven fibrous fillers and the use of fasteners of a simple design, such as a bolt and nut.

GENERAL CONCLUSIONS

In this diploma work were created:

- preliminary design of the long-range passenger aircraft with 250 seats capacity;
- the schematic design of the layout of the long-range aircraft with 250 passengers;
-the center of gravity of the airplane calculations;
-the calculation of the main geometrical parameters of the passenger equipment element;
- the design of passenger seat.

The created aircraft meets the intended purpose of use, its geometric characteristics will provide the necessary aerodynamic characteristics, which will lead to efficient use.

A new beam is used in design aircraft. It has better characteristics and will be more ecological and cheaper.

In the special part was improved the new floor beam that provide:

- reduce the weight of the structure by at least 40%;
- better ergonomics;
- more safe and eco-friendly;
- meet all the aviation requirements and standards.

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Appendix

Appendix A

PROJECT PLAN

NAU, AKF 402

PROJECT diploma Calculation completed 22.09.2021

Executor Meleschko Kseniia

Table of the airplane statistics data

Number of passengers	250.
Number of crew members	2.
Number of flight attendants	7.
The mass of equipment and service cargo	2469.12 kg.
Payload weight	26125.00kg.
Cruising speed	850. km/h
The number "M" flight at cruising speed	0.7870
The estimated height of the beginning of	
The implementation of flights with cruising economic speed	10.00 km
Flight range with maximum payload	5500. km.
The length of the runway of the home airfield	2.95 km.
Number of engine	2.
Estimated according to the statistics of thrust-to-weight ratio in n/kg...	2.3000
Pressure increasing ratio	32.50
The adopted bypass ratio of the engine	5.00
Optimal engine bypass ratio	5.00
Relative fuel mass according to statistics	0.3200
Wing aspect ratio	7.89
Wing constriction	5.00
Average relative wing thickness	0.120
Wing sweep at 0.25 chords	29.0 deg.
Mechanization degree of the wing	1.050
Relative area of root nodule	0.050

Wing profile - Supercritical

WHITCOMB Washers - Installed

Spoilers - installed

Fuselage diameter 5.00 м.

Fuselage elongation 9.80

The sweep of the horizontal tail 36.0 deg.

The sweep of the vertical tail 38.0 deg.

RESULT OF CALCULATION

The value of the optimal coefficient of lift at the design point

Cruise flight mode Su 0.44807

Coefficient value Cx.ind. 0.00914

DETERMINATION OF THE COEFFICIENT Dm = Mkrit - Mkreis

Cruising Mach number Mcreis 0.78701

Wave Crisis Mach number Mkrit0.79836

Calculated value Dm 0.01135

The values of the specific loads on the wing in kPA (over the full area): takeoff 6.163

In the middle of the cruising section 5.162 beginning of the cruising section 5.945

The value of the drag coefficient of the fuselage and nacelles 0.01114

Coeff value profile. wing and empennage dragоперения 0.00918

Aircraft drag coefficient value:

At the beginning of cruising 0.03190

Mid-cruise 0.03051

Average value of Su for a conditional flight over the ceilings 0.44807

Average cruising quality of the aircraft 14.68455

The value of the coefficient Su.pos. 1.574

Coefficient value (at stall speed) Su.p. max. 2.361

Coefficient value (at stall speed) Su.vol. Max. 1.948

The value of the coefficient Su.rep. 1.422

Thrust-to-weight ratio at the beginning of the cruise mode 0.619

Starting thrust-to-weight ratio according to cruise conditions. Ro.cr. 2.330

Starting thrust weapon. under the conditions of safe take-off Ro.takeoff. 3.127

Estimated thrust-to-weight ratio of the aircraft Ro 3.283

Ratio Dr = Ro.cr / Ro.vzd Dr 0.745

SPECIFIC FUEL CONSUMPTIONS (in kg / kN * h):

Takeoff	36.3619
Cruising (engine characteristic)	58.7076
Average cruising at a given flight range	64.0085

RELATIVE FUEL MASSES:

Aeronautical reserve	0.03923
Consumed mass of fuel	0.27327

VALUES OF THE RELATIVE MASSES OF THE MAIN GROUPS:

Wing	0.08952
Horizontal tail	0.00870
Vertical tail	0.00846
Landing gear	0.03707
Power Plant	0.09801
Fusulage	0.09352
Equipment and management	0.12466
Additional equipment	0.01159
Overhead	0.01865
Fuel at Lcalc.	0.31250
Payload	0.19737

Takeoff weight of the aircraft "M.o"= 132368. kg.

Required take-off thrust of one engine 217.30 N

The relative mass of high-altitude equipment and

Aircraft anti-icing system 0.0218

Relative mass of passenger equipment (or equipment for cargo aircraft cabins) 0.0152

Relative weight of decorative cladding and TZI 0.0074

Relative mass of household (or cargo) equipment 0.0142

Relative control mass 0.0052

Relative mass of hydraulic systems 0.0152

Relative mass of electrical equipment 0.0300

Relative mass of location equipment 0.0028

Relative mass of navigation equipment 0.0042

Relative mass of radio communication equipment 0.0021

Relative mass of instrumentation 0.0049

Relative mass of the fuel system (included in the "SU" mass) 0.0094

Additional equipment:

Relative weight of container equipment 0.0076

Relative weight of atypical equipment 0.0040

[built-in diagnostic and parameter control systems,

Additional equipment of salons, etc.]

TAKE-OFF CHARACTERISTICS

Aircraft take-off speed 299.68 km/h

Acceleration during takeoff 2.60 m/s*s

The takeoff run of the aircraft 1330. m.

Distance to climb a safe height 578. m.

Takeoff distance 1908. m.

TAKE-OFF CHARACTERISTICS

CONTINUED TAKE-OFF

Decision speed 284.70 km/h Average acceleration during continuous take-off on a wet runway 0.37m/s*s

The take-off run at a continued take-off on a wet runway 2088.28 m.

The takeoff distance of the continued takeoff 2666.66 m.

The required length of the runway according to the conditions

Rejected takeoff 2760.77 m.

LANDING DISTANCE CHARACTERISTICS

The maximum landing weight of the aircraft 101626. kg. The time of descent from an echelon altitude to a circling altitude 20.8 min.

Descent distance 49.19 km.

The landing approach speed 268.37 km/h.

Average vertical sink rate 2.13 m/s

Distance of the air section 524. m.

Landing speed 253.37 km/h.

The length of the run 852. m.

Landing distance 1376. m.

Required runway length (RWY + CPB) for

Main airfield 2298. m.

The required length of the runway for the alternate airfield 1954. m.

AIRCRAFT PERFORMANCE INDICATORS

The ratio of the mass of the equipped aircraft to

Payload weight 2.4249

Weight of empty equipped with-that parish. for 1 passenger 253.40kg/pas.

Relative performance under full load 433.39 km/h

Productivity with-that at max. commercial load 21222.3 kg*km/h

Average fuel consumption per hour 5342.543 kg/h

Average kilometer fuel consumption 6.58 kg/km

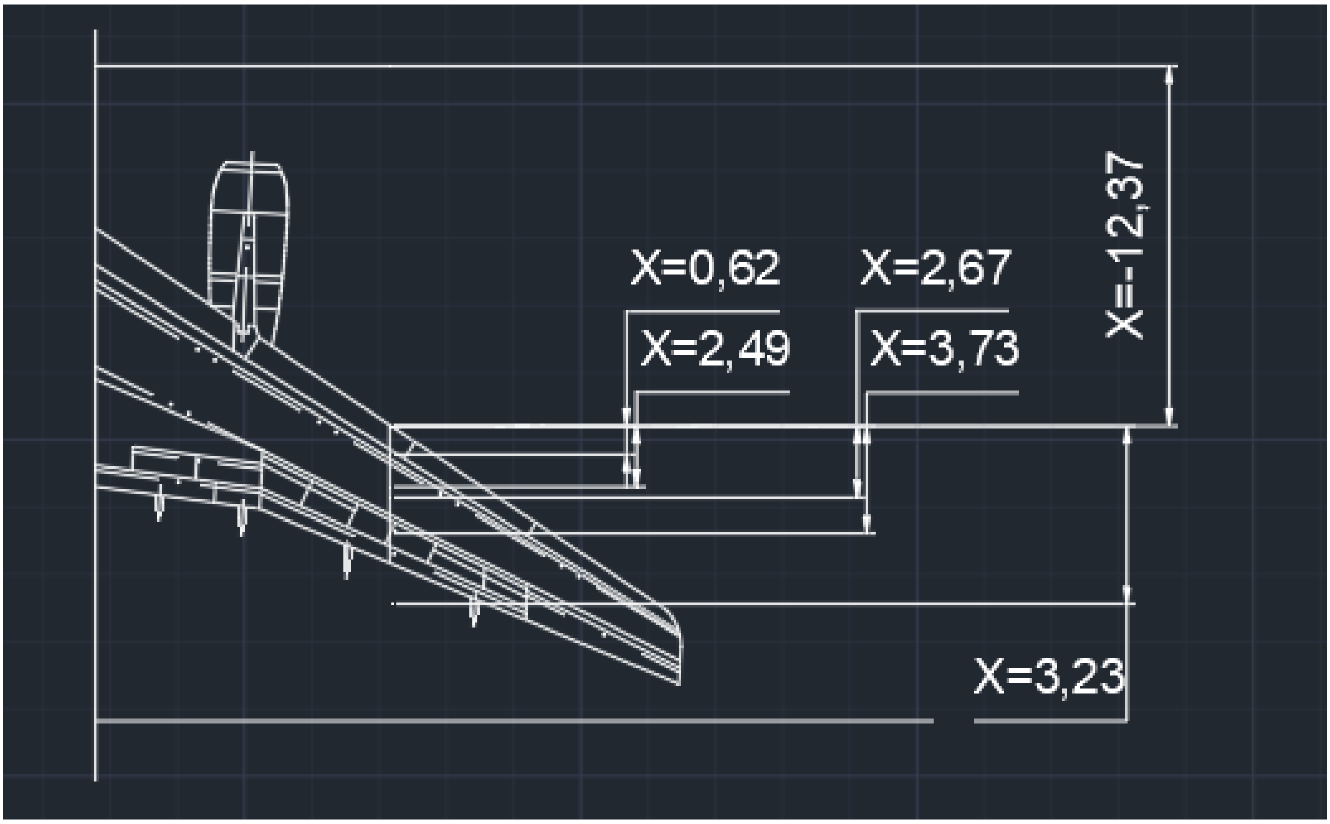
Average fuel consumption per ton-kilometer 251.742 g/(t*km)

Average fuel consumption per passenger kilometer 23.2121 g/(pas. *km)

A rough estimate is given. cost per ton-kilometer 0.3375 $/(t*km)

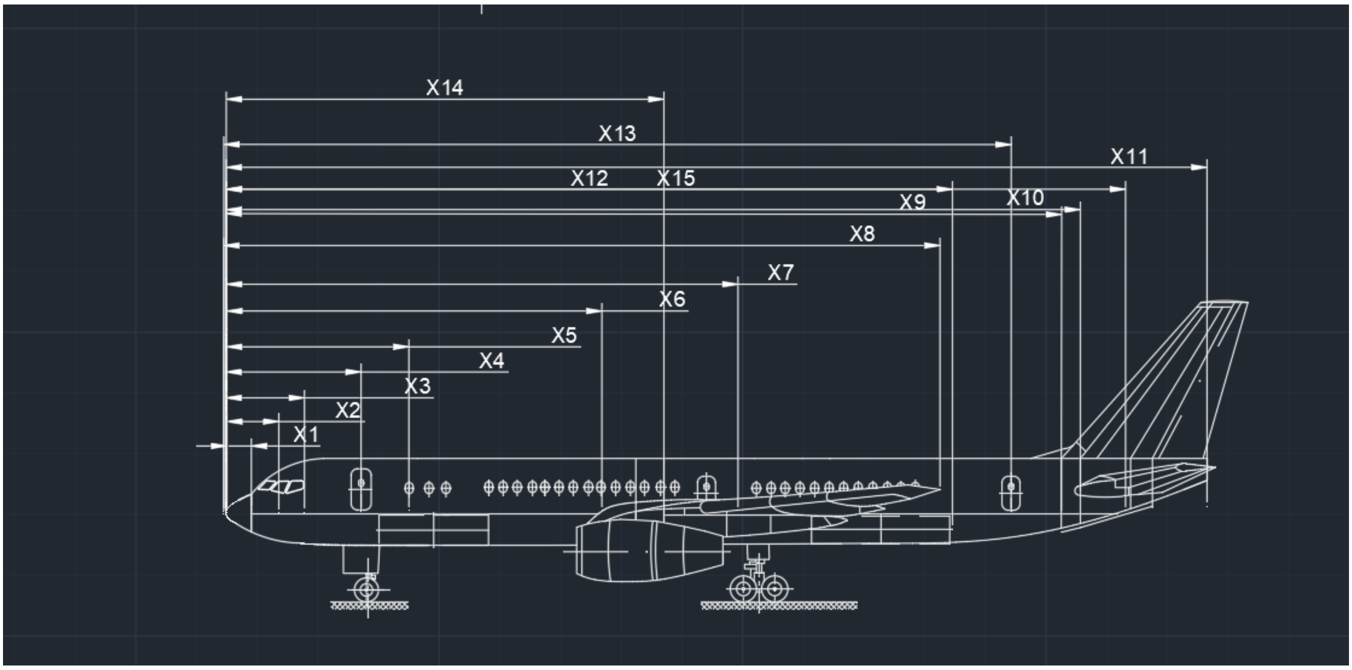
Apendix B

Centering of the wing

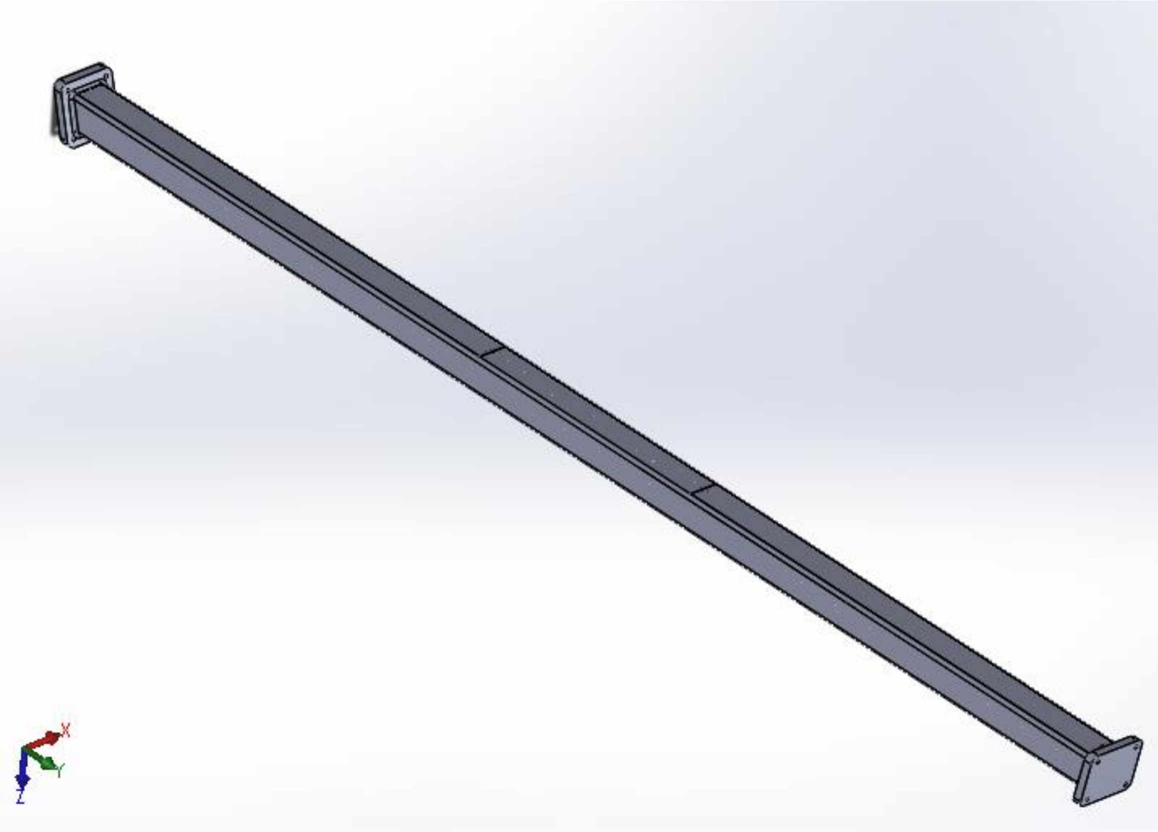


Apendix C

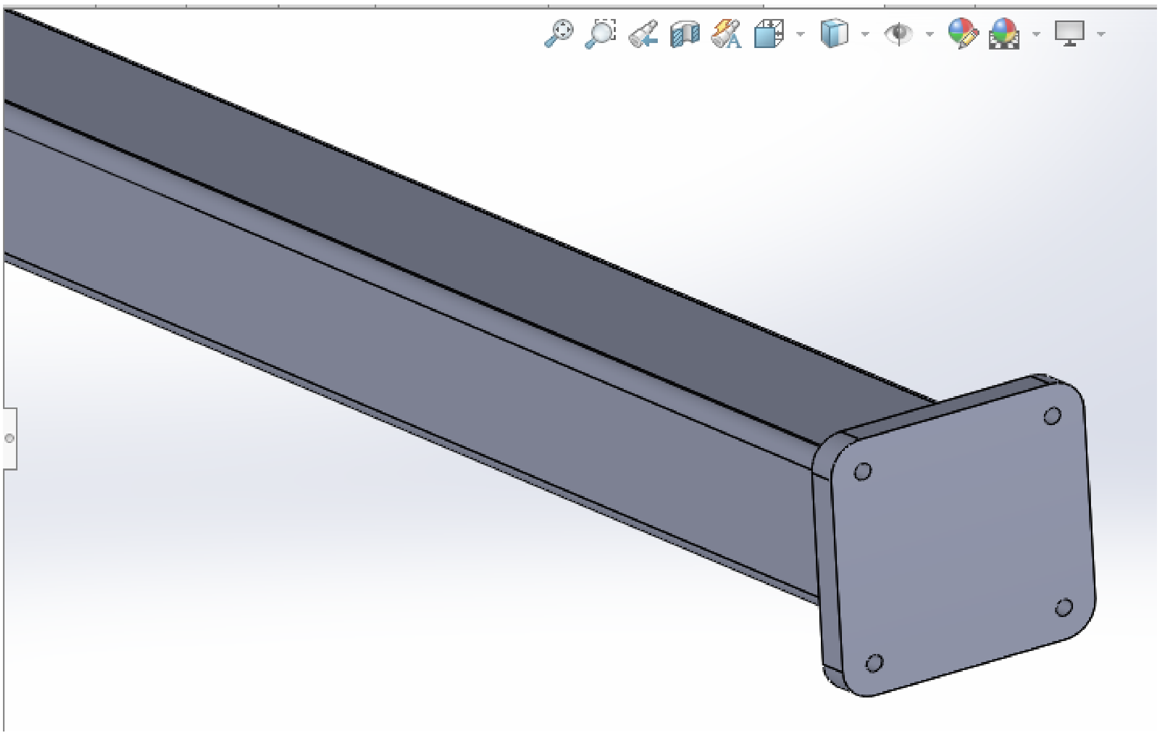
Centering of the fuselage



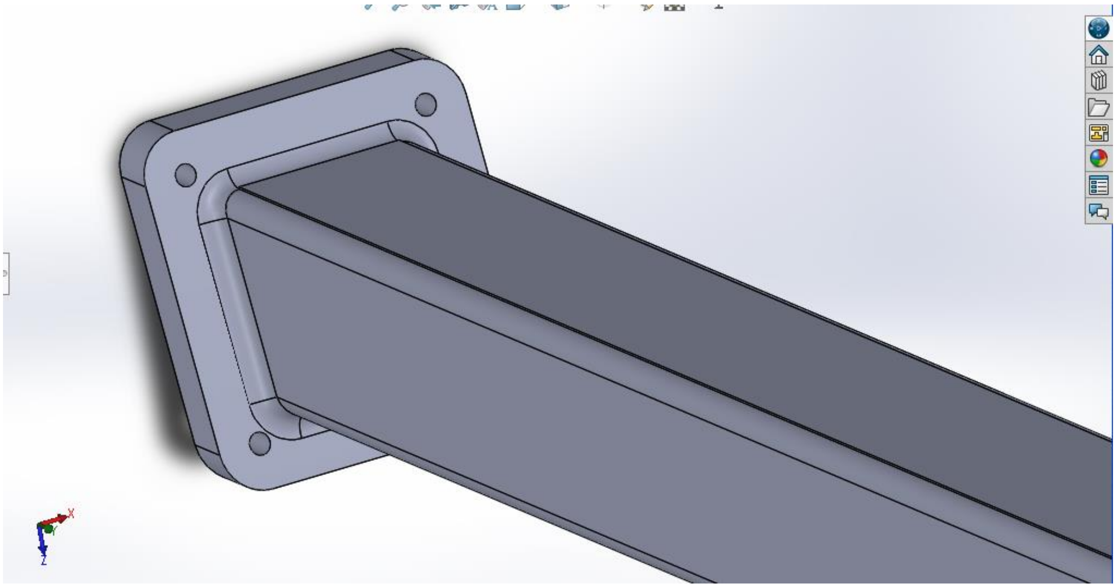
Apendix D



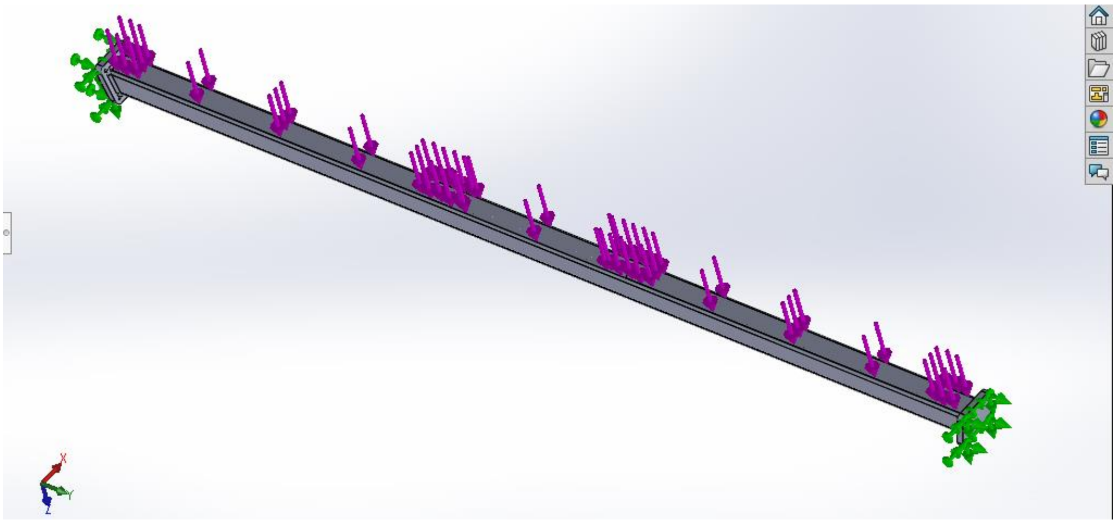
General view of the beam



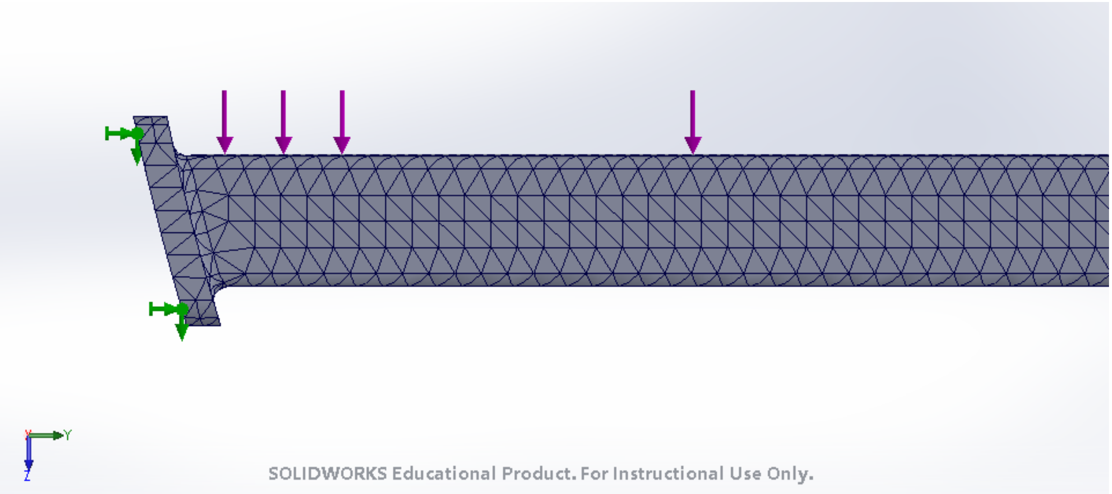
Fastening the beam to the fuselage



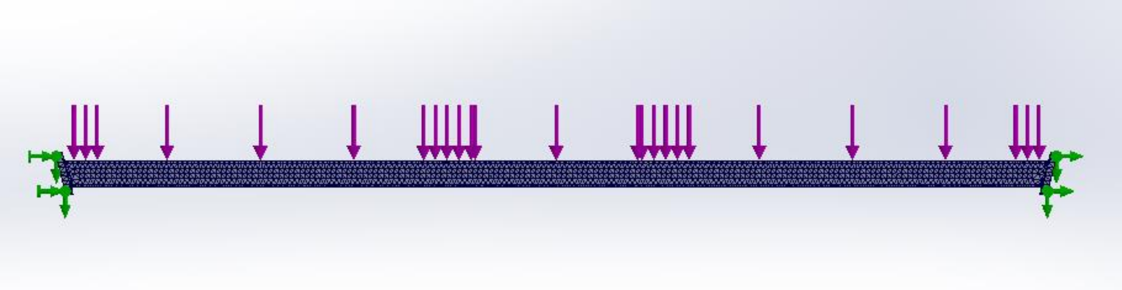
Fastening the beam to the fuselage



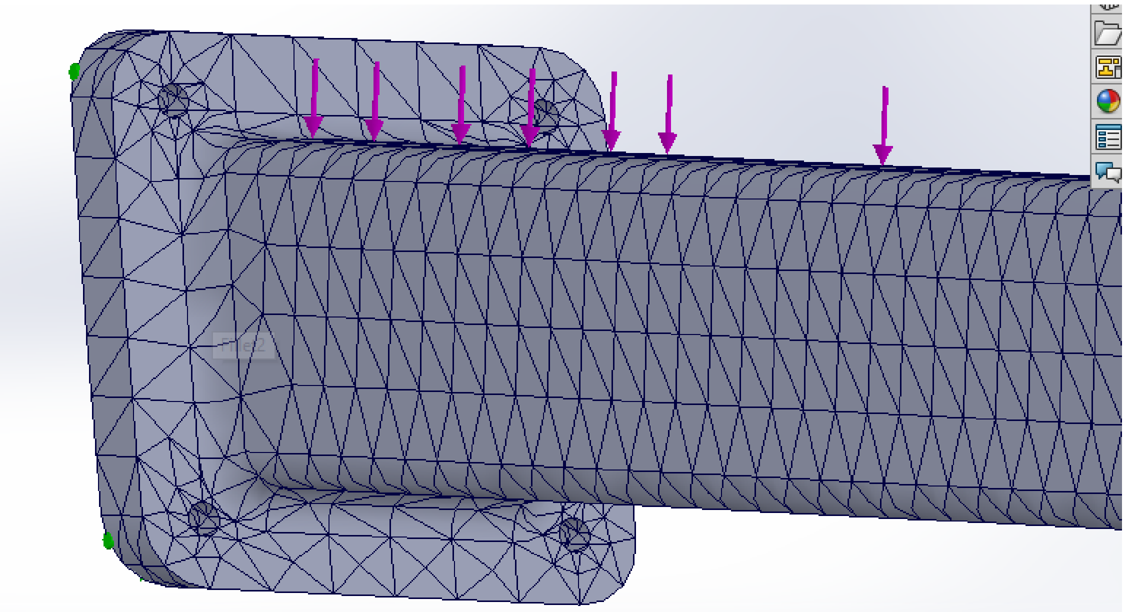
Load distribution on the beam



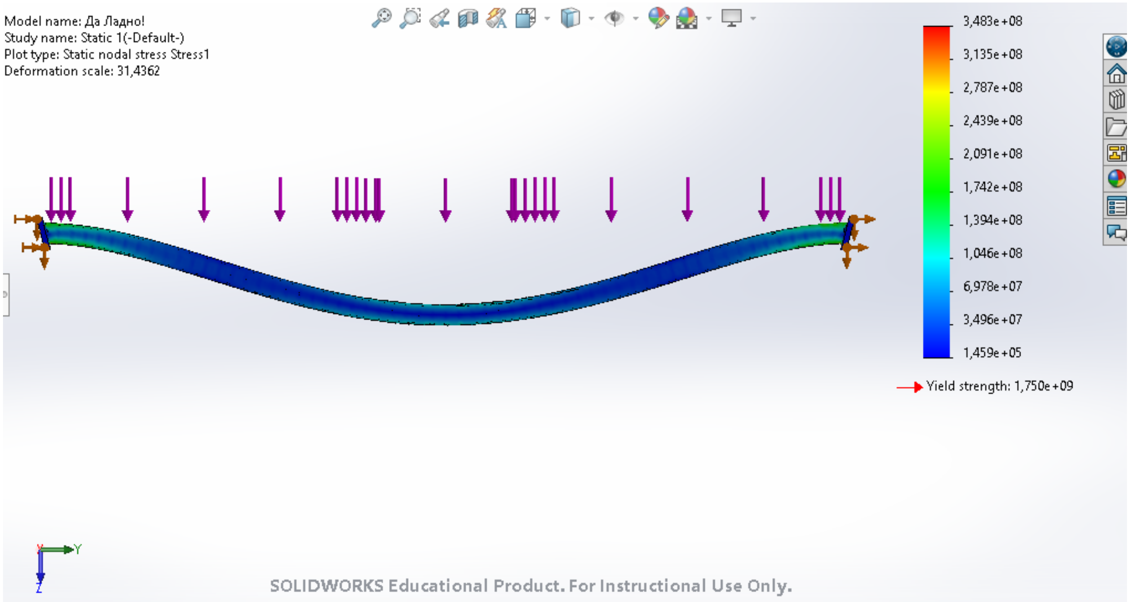
Dividing a beam into a mesh for strength analysis



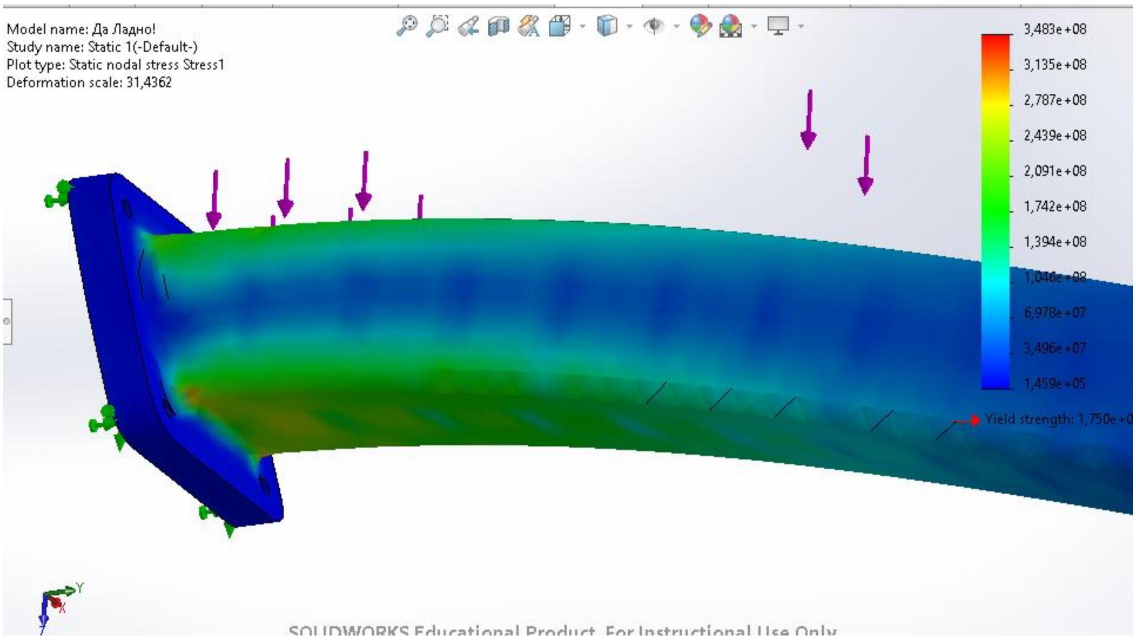
Distribution of the load on the beam, which is divided into a grid for strength calculation



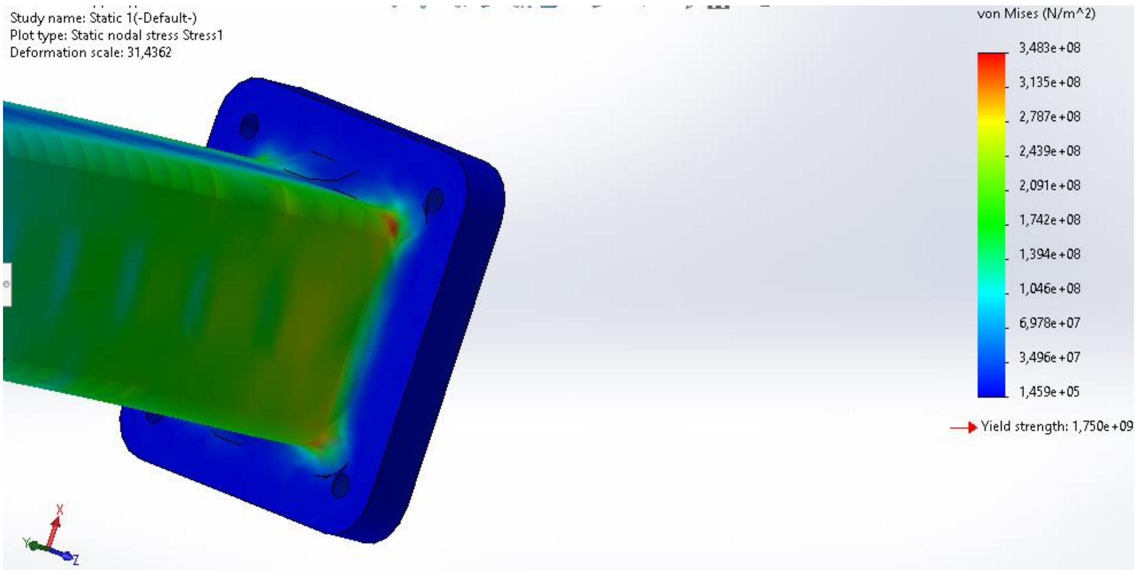
Distribution of the load on the beam, which is divided into a grid for strength calculation



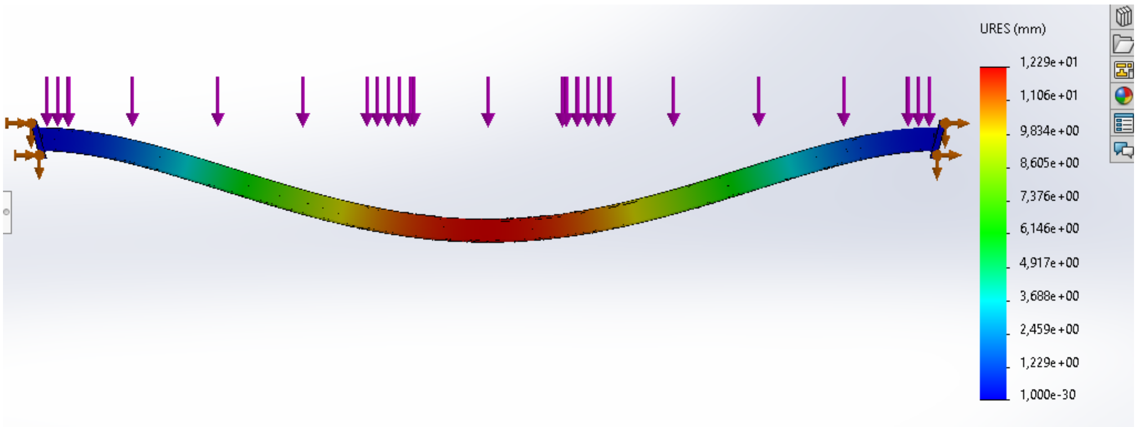
Stress analysis



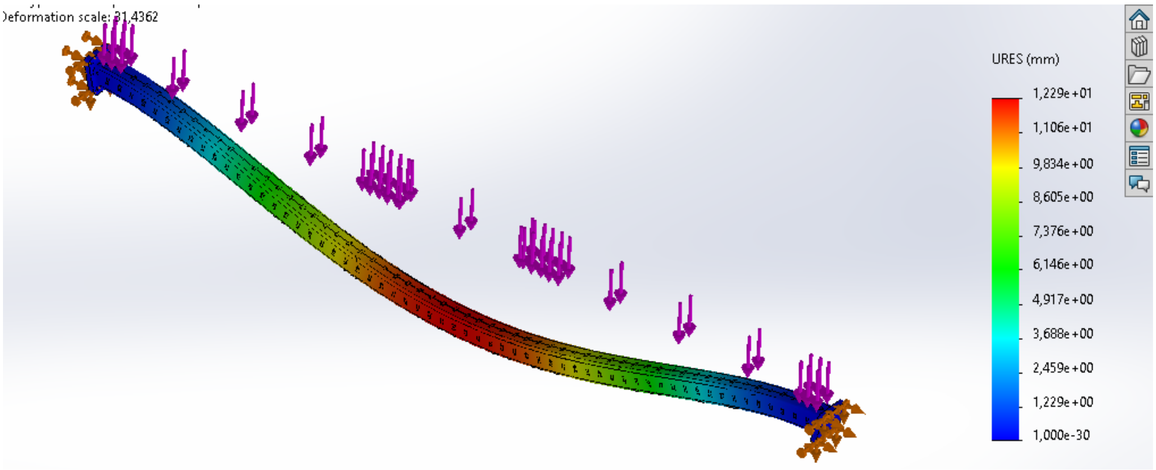
Stress analysis of beam end



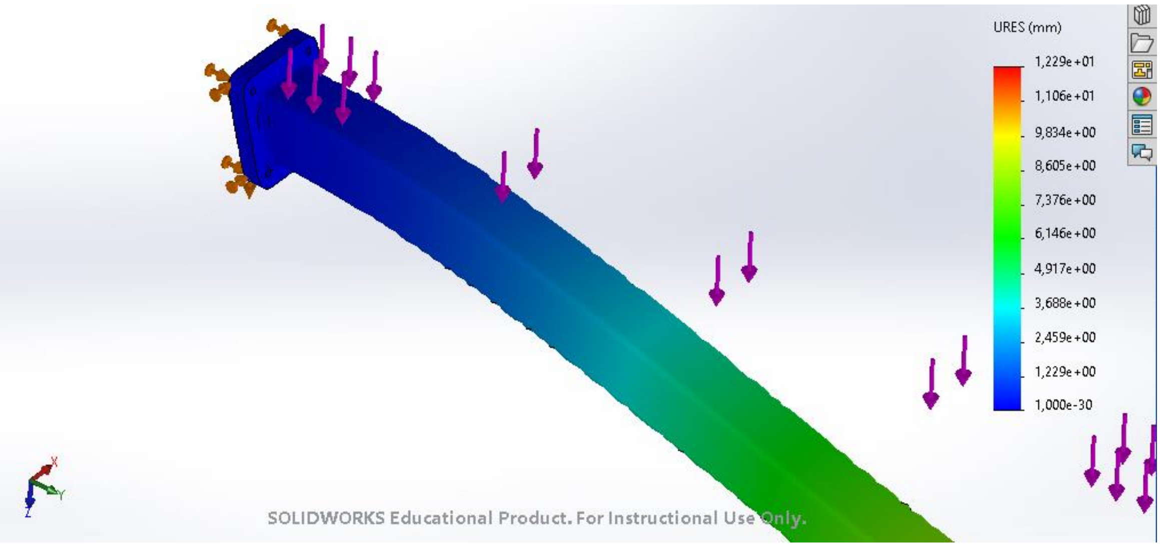
Stress analysis of beam attachment to the fuselage



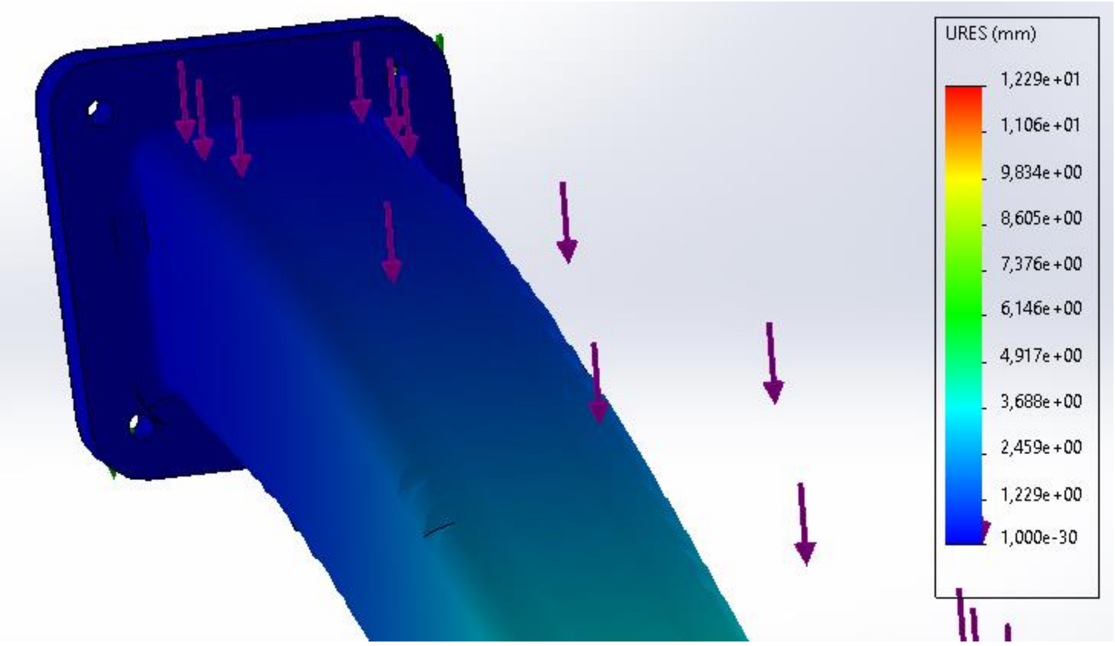
Displacement analysis



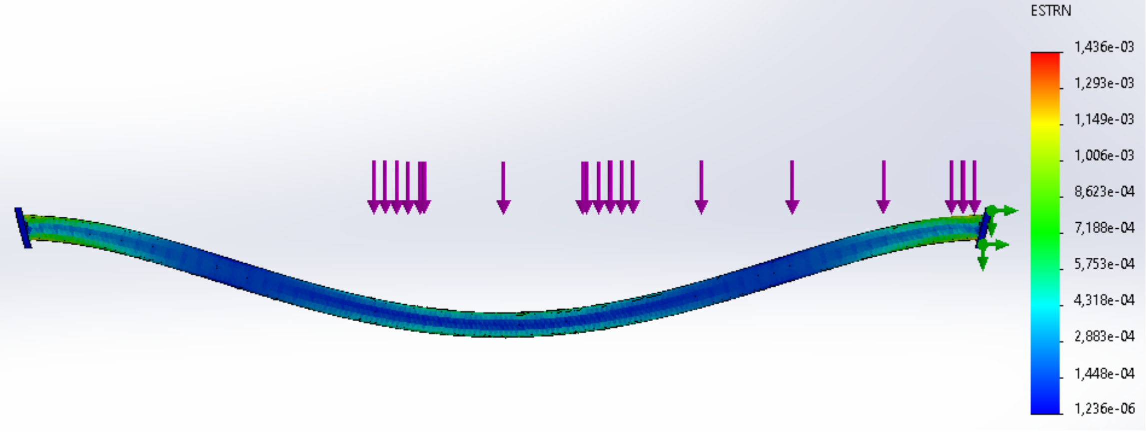
Displacement analysis



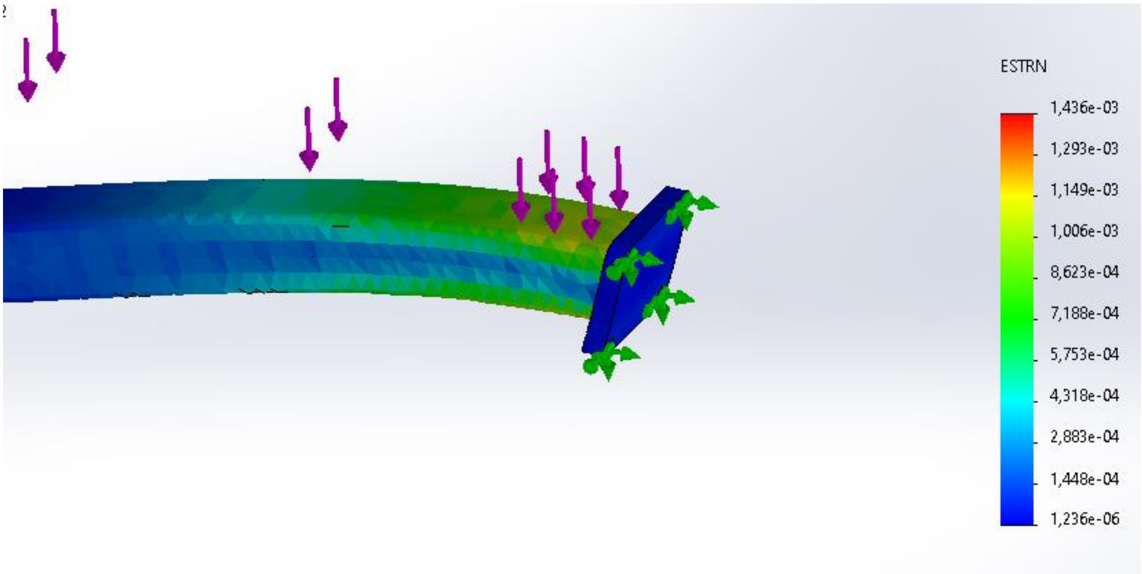
Displacement analysis of beam end



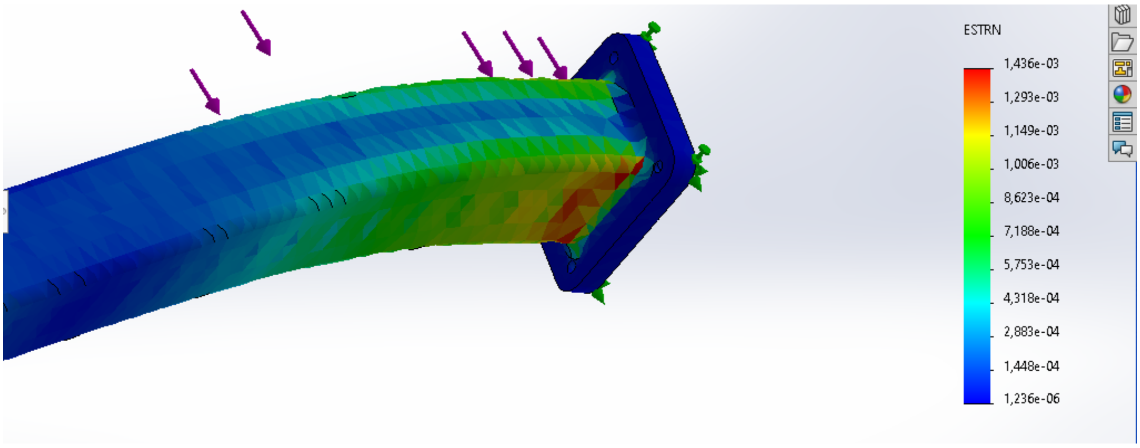
Displacement analysis of beam attachment to the fuselage



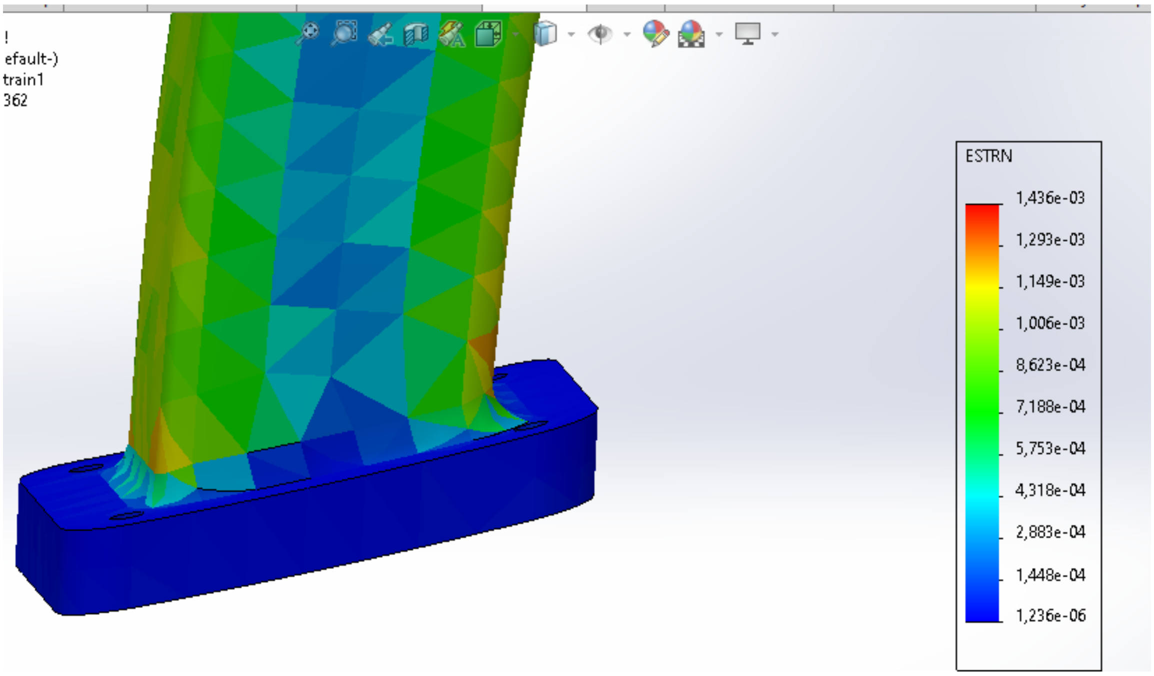
Strain analysis of beam



Strain analysis of beam end



Strain analysis of beam end



Strain analysis of beam attachment to the fuselage