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«___» _____ 2024 р.

КВАЛІФІКАЦІЙНА РОБОТА
ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ
«БАКАЛАВР»

Тема: «Механізм регулювання висоти пасажирського крісла»

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MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
National Aviation University
Department of Aircraft Design

PERMISSION TO DEFEND

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" ____ " _____ 2024

BACHELOR DEGREE THESIS

Topic: "Passenger Seat Height Adjustment Mechanism"

Fulfilled by: _____ **Kyrylo SYDORENKO**

Supervisor: _____ **Tetiana MASLAK**
PhD, associate professor

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Kyiv 2024

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

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ЗАТВЕРДЖУЮ

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«_____» _____ 2024 р

ЗАВДАННЯ

на виконання кваліфікаційної роботи здобувача вищої освіти

СИДОРЕНКА КИРИЛА ОЛЕКСАНДРОВИЧА

1. Тема роботи: «Механізм регулювання висоти пасажирського крісла», затверджена наказом ректора від 15 травня 2024 року № 794/ст.
2. Термін виконання роботи: з 20 травня 2024 р. по 16 червня 2024 р.
3. Вихідні дані до роботи: максимальна кількість пасажирів 240, дальність польоту з максимальним комерційним навантаженням 6000 км, крейсерська швидкість польоту 850 км/год, висота польоту 10 км.
4. Зміст пояснювальної записки: вступ, основна частина, що включає аналіз літаків-прототипів і короткий опис проєктованого літака, обґрунтування вихідних даних для розрахунку, розрахунок основних льотно-технічних та геометричних параметрів літака, компоновання пасажирської кабіни, розрахунок центрування літака, спеціальна частина, яка містить розробку, опис роботи та перевірку на міцність механізму регулювання висоти сидіння призначеного для сидінь бізнес-класу.
5. Перелік обов'язкового графічного (ілюстративного) матеріалу: загальний вид літака (A1×1), компоновальне креслення фюзеляжу (A1×1), 3D модель механізму регулювання висоти крісла (плакати).

6. Календарний план-графік:

№	Завдання	Термін виконання	Відмітка про виконання
1	Вибір вихідних даних, аналіз льотно-технічних характеристик літаків-прототипів.	20.05.2024 – 21.05.2024	
2	Вибір та розрахунок параметрів проектного літака.	22.05.2024 – 23.05.2024	
3	Виконання компоунування літака та розрахунок його центрування.	24.05.2024 – 25.05.2024	
4	Розробка креслень по основній частині роботи.	26.05.2024 – 27.05.2024	
5	Огляд літератури за проблематикою роботи. Створення 3D моделі механізму регулювання висоти крісла.	28.05.2024 – 29.05.2024	
6	Проведення розрахунків на міцність.	30.05.2024 – 31.05.2024	
7	Оформлення пояснювальної записки та графічної частини роботи.	01.06.2024 – 02.06.2024	
8	Подача роботи для перевірки на плагіат.	03.06.2024 – 06.06.2024	
9	Попередній захист кваліфікаційної роботи.	07.06.2024	
10	Виправлення зауважень. Підготовка супровідних документів та презентації.	08.06.2024 – 10.06.2024	
11	Захист кваліфікаційної роботи.	11.06.2024 – 16.06.2024	

7. Дата видачі завдання: 20 травня 2024 року

Керівник кваліфікаційної роботи _____

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Educational Degree "Bachelor"
Specialty 134 "Aviation and Aerospace Technologies"
Educational Professional Program "Aircraft Equipment"

APPROVED BY

Head of the department,
Associate Professor, PhD.

_____Sviatoslav YUTSKEVYCH
" _____ " _____ 2024

TASK

for the bachelor degree thesis

Kyrylo SYDORENKO

1. Topic: "Passenger Seat Height Adjustment Mechanism", approved by the Rector's order № 794/CT from 15 May 2024.
2. Period of work: since 20 May 2024 till 16 June 2024.
3. Initial data: 240 passengers, flight range with maximum capacity 6000 km, cruisespeed 850 km/h, flight altitude 10 km.
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: designing and stress-state analysis of the seat height adjustment mechanism for business class seats.
5. Required material: general view of the airplane (A1×1), layout of the airplane (A1×1), 3D model of the seat height adjustment mechanism for the passenger seat.

6. Thesis schedule:

№	Task	Time limits	Done
1	Selection of initial data, analysis of flight technical characteristics of aircraft prototypes.	20.05.2024 – 21.05.2024	
2	Selection and calculation of the aircraft designed parameters.	22.05.2024 – 23.05.2024	
3	Performing of aircraft layout and centering calculation.	24.05.2024 – 25.05.2024	
4	Development of drawings on the thesis main part.	26.05.2024 – 27.05.2024	
5	Creation of a 3D model of the height adjustment mechanism.	28.05.2024 – 29.05.2024	
6	Carrying out strength calculations. Processing of experimental data.	30.05.2024 – 31.05.2024	
7	Explanatory note checking, editing, preparation of the diploma thesis graphic part.	01.06.2024 – 02.06.2024	
8	Submission of the work to plagiarism check.	03.06.2024 – 06.06.2024	
9	Preliminary defense of the thesis.	07.06.2024	
10	Making corrections, preparation of documentation and presentation.	08.06.2024 – 10.06.2024	
11	Defense of the diploma thesis.	11.06.2024 – 16.06.2024	

7. Date of the task issue: 20 May 2024

Supervisor: _____

Tetiana MASLAK

Student: _____

Kyrylo SYDORENKO

РЕФЕРАТ

Пояснювальна записка кваліфікаційної роботи бакалавра
«Механізм регулювання висоти пасажирського крісла»:

72 с., 31 рис., 9 табл., 6 джерел

Представлена робота присвячується проектуванню далекомагістрального літака, призначеного для перевезення 240 пасажирів.

Метою роботи є створення аванпроекту середньомагістрального пасажирського літака та визначення його основних льотно-технічних характеристик. Основним предметом розробки є механізм регулювання висоти пасажирського крісла.

У роботі використовується метод порівняльного аналізу літаків – прототипів для вибору найбільш обґрунтованих технічних рішень, а також методи інженерних розрахунків для отримання основних параметрів проєктованого літака.

У спеціальній частині необхідно розробити механізм регулювання висоти пасажирського крісла. Головна актуальність роботи полягає в підвищенні комфорту, оскільки можливість змінити висоту крісла допоможе забезпечити найкращу висоту крісла індивідуально для кожного пасажирів і зробить переліт ще зручнішим.

Практичне значення кваліфікаційної роботи полягає в підвищенні ефективності пасажирських перевезень. Результати роботи можуть бути використані в авіаційній галузі та в навчальному процесі студентів авіаційних спеціальностей.

Кваліфікаційна робота, аванпроект літака, компоновання, центрування, пасажирське обладнання, крісло

ABSTRACT

Bachelor degree thesis "Passenger Seat Height Adjustment Mechanism"

72 pages, 31 figures, 9 tables, 6 references

A long-haul passenger aircraft designed to carry 240 passengers is being developed.

The objective of the work is to create a preliminary design of a long-range passenger aircraft and determine its key flight and technical characteristics. The main focus of the thesis is on a passenger equipment in the cabin, on the seat height adjustment mechanism.

The thesis employs a method for the analysis of aircraft prototypes to select the most appropriate technical data for designing aircraft, as well as engineering calculation methods to obtain the primary geometrical parameters and mass balance of the aircraft.

The special part is devoted to the comfort of passengers in the passenger compartment. To provide the ergonomic design of the passenger seat and possibility to change the height of the seat, the design of the seat height adjustment mechanism has to be developed.

The practical value of the thesis is presented by the efficiency and comfort of passenger transportation. The results of the work can be applied in the aviation industry and in the educational process for aviation students.

Bachelor thesis, preliminary design, cabin layout, center of gravity calculation, passenger equipment, seat

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INTRODUCTION

Passenger airplanes today represent amazing technological advancements that have changed the way people move around the world. They provide comfort and speed, allowing passengers to travel vast distances in a short time, and play an important role in global economic and sociocultural integration. Compared to other modes of transport, airplanes have a number of advantages:

- Airplanes are capable of crossing vast distances in a short time. This makes them an excellent choice for long flights and international travel.
- Modern aircraft offer passengers wide seats, varied meals and on-board entertainment, which makes travel more comfortable.
- Unlike cars and public transport, airplanes are not subject to traffic jams and do not depend on the state of the infrastructure.

Unfortunately, flying on airplanes can cause a number of inconveniences for passengers:

- Traveling by plane is usually more expensive than using other modes of transport, especially over short distances.
- Airports and regular airlines are not available everywhere, so aircraft availability may be limited in some regions.
- Travel by air is subject to strict security regulations, including border controls and additional checks, which may cause inconvenience and delays.
- Despite the flight's fast speed, the time spent waiting to board, go through security, and disembark can make air travel less efficient over short distances.

The goal of my coursework will be to create long and middle range passenger aircraft with 240 passenger capacity.

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1. PROTOTYPE ANALYSIS AND DESCRIPTION OF ITS MAIN PARTS

1.1. Selection of the projected data

To ensure a high standard of quality and safety when creating an aircraft, it is necessary to carefully determine the best parameters of its design, including flight performance, weight, geometric, aerodynamic and economic characteristics.

As prototypes, I decided to take three medium and long-haul aircraft: B737, A320 and A310. Based on these three prototypes, I plan to create a new competitive aircraft. Statistic data of prototypes are presented in table 1.1.

Table 1.1

Performances of prototypes

Parameters	Aircraft		
	B737	A320	A310
The purpose of airplane	Passenger	Passenger	Passenger
Crew/flight attendant	2/6	2/5	2/7
Maximum take-off weight, kg	88 300	78 000	144 000
Max payload, kg	72 574	19 900	32 834
Passenger's seat	204	186	220
Flight altitude, m	12 500	12 500	12 527
Flight range, km	7 130	6 100	6 500
Take off distance, m	2 316	2 100	2 550
Number and type of engines	2 (CFM LEAP-1B)	2 (IAE V2500-A5)	2 (GE CF6-80C2A2)
Fuselage cross-section	circular	circular	circular
Fuselage diameter, m	3.8	3.95	5.64
Fuselage length, m	43.8	37.57	45.13
Sweepback angle on 1/4 chord,	25	25	28

This scheme is determined by the relative location of the aircraft units, their number and shape. The aerodynamic and flight characteristics of the aircraft depend

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on the layout of the aircraft and its aerodynamic scheme. A correctly selected concept can increase not only the economic efficiency of the aircraft, but also the safety and regularity of flights.

1.2. Description of the main parts of the aircraft

This airplane is a long-range cantilever low-wing monoplane with two bypass turbojet engines installed in nacelles on pylons under the wing. The plane has tricycle landing gear with a nose single-strut landing gear and two main gears.

A swept wing has a high aspect ratio and it is based on a new supercritical profile. Fuselage has circular cross section. Empenage has a conventional construction, with adjustable vertical stabilizer mounted on the fin.

The fuselage is a semi-monocoque frame with a round section. The main material of construction is high-strength aluminum alloy; individual elements are made of steel and titanium. The fuselage structure consists of frames and stringers, stressed skin.

In the front part of the fuselage there is a two-seat crew cabin. Luggage and cargo compartments are located under the floor; the compartments are sealed.

The airframe uses new heat-treated aluminum-zinc alloys to provide increased strength and corrosion resistance. Particular attention is paid to corrosion resistance. Each structural element was subjected to chromic acid anodizing, primed and painted. All fasteners were treated with corrosion inhibitors. Also, composite materials based on Kevlar or carbon fibers were widely used in the airframe design. The use of composite materials in the aircraft design ensured a weight savings.

An aircraft's wing is an important element of its design, providing optimal aerodynamic performance and flight efficiency. The wing is cantilever, swept, two-spar, made of high-strength aluminum alloys and composite materials. Monolithic cladding panels are widely used in the design. This simplifies assembly, reduces manufacturing costs, and provides weight savings compared to prefabricated components.

The wing has a supercritical profile optimized for a cruising speed of Mach 0.787. This feature reduces aerodynamic drag and improves the overall performance of the aircraft in various phases of flight.

The main structural tanks are located in the wings and the center box between the spars, as is very typical for airliners. There are five fuel tanks (two in each wing and one in the center locker). This aircraft can carry up to 66,000 liters of fuel. This fuel is enough for intercontinental flights, for example, from New York to London.

An emergency wind turbine located between the fuselage and the right engine maintains pressure in the yellow hydraulic system in a pinch. All instruments in the cabin are located in the front and on the ceiling. The cockpit is designed for two crew members: the pilot-commander (captain) and the pilot-co-pilot (copilot).

There are six screens that provide a wealth of information for two pilots, but they are complemented by traditional electromechanical instruments. The aircraft is equipped with an EFIS (Electronic Flight Instrument System), information about which is displayed on two cathode ray screens for each pilot. The upper screen displays the attitude indicator as well as information about speed (knot speed, change in speed, Mach number, target speed according to the flight plan) and altitude (radar altimeter, target speed).

To the right of the top screen are an electromechanical altimeter and a variometer. The reactor control and monitoring instruments, located in the center of the instrument panel, are entirely electromechanical.

The screens, located in the central part of the instrument panel, between the two pilots, refer to the ECAM (Electronic Centralized Aircraft Monitor). ECAM displays extensive system information (electrical, hydraulic, pneumatic, flight controls, lighting, defrost, fault messages, etc.) that was previously communicated through a suite of dedicated tools. Additionally, it uses a graphical representation rather than a numerical notation, making it easier to read: any situation that does not meet expectations will be displayed in red, a relevant situation in green, and an optional situation in white.

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The aircraft's cabin meets the highest standards of comfort and functionality, providing excellent features such as wide visibility, minimal noise levels, efficient air conditioning and adjustable seats. Pilot seats provide comfort and support for extended periods of flight.

The aircraft has a three-post retractable landing gear. The nose strut retracts forward and has dual wheels that are steerable when taxiing. The rack is retracted using a hydraulic cylinder, and released under the influence of gravity. Each main strut has a two-axle, four-wheeled trolley that retracts into the fuselage. The wheels are equipped with anti-skid devices and carbon disc brakes. All supports have oil-air shock absorption. To protect the structure during takeoff and landing at high pitch angles, a tail bumper is provided.

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Conclusions to the analytical part

Based on the results of the study and analysis of the characteristics of prototype aircraft, a long-range aircraft with a capacity of up to 240 passengers was developed. A310 was chosen as the main prototype for development. Features of choosing this aircraft are:

- economical fuel consumption compared to other models. This makes it more profitable to operate on medium and long routes;
- it has a good passenger capacity with relatively small dimensions, which allows it to be used effectively on routes with medium and high loading;
- it can be used on both short and long-haul routes, thanks to which airlines can plan their flights depending on demand;
- it offers a high level of passenger comfort thanks to its spacious cabin and comfortable seats.

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2. AIRCRAFT MAIN PARTS CALCULATIONS

2.1. Geometry calculations for the main parts of the aircraft

When creating a preliminary design of an aircraft, it is important to take into account the basic geometric characteristics of all its components. In this paragraph we will look at calculations for the wing, fuselage geometry and cockpit layout, as well as the structure of the landing gear and tail. When selecting engines, we use a list that includes engines currently in service.

2.1.1. Wing geometry calculation

For aircraft design, the initial information has been computed using a specialized computer program developed at the Aircraft Design Department of NAU. The details can be found in Appendix A (Initial Data of Aircraft).

In the preliminary design phase, it is customary to select an airfoil from the extensive range available in aeronautical literature, each providing geometric and aerodynamic characteristics.

Supercritical airfoil was taken for designing aircraft. Relative thickness of the airfoil is 0.118. Location of the wing on fuselage: low-wing. Aspect ratio of the wing $\lambda_w = 8.80$. Taper ratio of the wing $\eta_w = 3.53$. The taper ratio influences the following quantities: structural weight, ease of fabrication, induced drag. Sweep back angle of a wing is 28.0 degree.

Wing area (S_{wing}): this is calculated from the wing loading and gross weight which have been already decided, (in appendix A).

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<i>Project part</i>							

$$S_{wing} = \frac{m_0 \cdot g}{P_0} = \frac{154701 \cdot 9.8}{5148} = 294 \text{ m}^2,$$

where m_0 – take off mass of the aircraft;

g – gravitational acceleration;

P_0 – wing loading at cruise regime of flight.

Following the calculations, we compare the wing area of our design with that of prototypes, and if necessary, we may proceed with recalculations.

So, we take the wing area $S_{wing} = 294 \text{ m}^2$.

Wing span is:

$$l = \sqrt{S_{wing} \cdot \lambda_w} = \sqrt{294 \cdot 8.8} = 51 \text{ m}.$$

Root chord is:

$$C_{root} = \frac{2S_w \eta_w}{(1 + \eta_w) \cdot l} = \frac{2 \times 294 \cdot 3.53}{(1 + 3.53) \cdot 51} = 9 \text{ m}.$$

Tip chord is:

$$C_{tip} = \frac{C_{root}}{\eta_w} = \frac{9}{3.53} = 2.55 \text{ mm}.$$

On board chord for trapezoidal shaped wing is:

$$C_{board} = C_{root} \cdot \left(1 - \frac{(\eta_w - 1) \cdot D_f}{\eta_w \cdot l_w}\right) = 9 \cdot \left(1 - \frac{(3.53 - 1) \cdot 5.64}{3.53 \cdot 51}\right) = 8.287 \text{ m}.$$

To select the structural scheme for the wing, it is necessary to identify the type of its internal design. The torsion box type with two spars was chosen for balancing the need for strength while concurrently ensuring a relatively lightweight structure.

Relative coordination of the spar's position for a wing with two spars is equal $x_{1spar} = 0.2 \cdot C_i$, $x_{2spar} = 0.6 \cdot C_i$; from the leading edge of current chord in the wing cross-section.

The spars are shown at the drawing (appendix B).

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Mean aerodynamic chord definition. The geometrical method of mean aerodynamic chord determination has been taken, which is presented at Appendix B and at the fig.2.1.

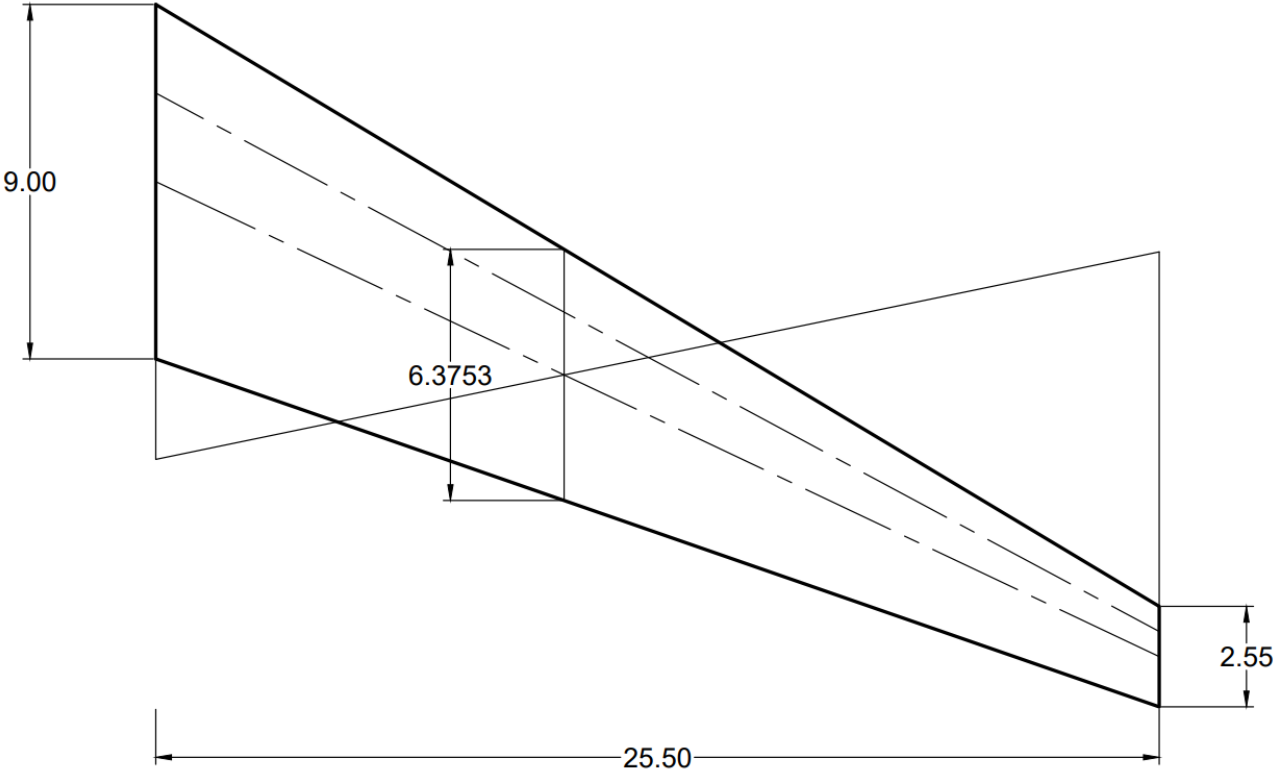


Fig. 2.1. Determination of mean aerodynamic chord.

Mean aerodynamic chord is equal $b_{MAC} = 6.3753 \text{ m}$.

Also MAC could be calculated the by the approximately formula for trapezoidal wing shape:

$$b_{MAC} = \frac{2}{3} \cdot \frac{C_{root}^2 + C_{root} \cdot C_{tip} + C_{tip}^2}{C_{root} + C_{tip}} = \frac{2}{3} \cdot \frac{9^2 + 9 \cdot 2.55 + 2.55^2}{9 + 2.55} = 6.3753 \text{ m}.$$

Once the geometric characteristics of the wing are having been determined, we can proceed to assess the geometry of the ailerons and high-lift devices.

The main purpose of the ailerons is to create rolling moment and provide adequate rate of roll. Ailerons geometrical parameters are determined by the next formulas:

Ailerons span:

$$l_{aileron} = 0.35 \cdot \frac{l_{wing}}{2} = 0.35 \cdot \frac{51}{2} = 8.925 \text{ m.}$$

Ailerons chord is taken from statistic data of prototypes and approximately is:

$$C_{aileron} = 0.24 \cdot C_i.$$

Aileron area:

$$S_{aileron} = 0.06 \cdot \frac{S_w}{2} = 0.06 \cdot \frac{294}{2} = 8.82 \text{ m}^2.$$

Ailerons are equipped by the secondary control surfaces (aerodynamic balance).

Trim tabs area:

$$S_{in \text{ axial}} = 0.3 \cdot S_{aileron} = 0.3 \cdot 8.82 = 2.496 \text{ m}^2.$$

Range of aileron deflection: upward $\delta_{aileron} \geq 25^\circ$ and downward $\delta_{aileron} \geq 15^\circ$.

The main task of determining the geometric parameters of the wing high-lift devices is to achieve predetermined coefficients of maintaining lift during takeoff and landing. These coefficients were taken into account in previous calculations for the selected rate of high-lift devices and airfoil type.

Because we have high-lift device coefficient = 0.97 we choose double slotted flaps together with slats which is best suited for our type of high lift device because it provides better aerodynamic characteristics. Double slotted flaps and slats work together to significantly increase the overall lift generated by the wing. This is crucial during takeoff and landing when the aircraft needs maximum lift to become airborne or touch down at lower speeds. Also the use of slats and double slotted flaps lowers the stall speed of the aircraft. This is essential for safe and controlled flight during approach and landing, allowing the aircraft to operate at lower speeds without risking a stall. The combination of these devices provides improved control characteristics, especially at

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low speeds and high angles of attack. This is beneficial for maintaining stable flight during critical phases such as approach and landing.

The relative coordination of high-lift devices on the wing chord are:

$$C_f = (0.28...0.3) C_i \text{ – for one slotted and two slotted flaps;}$$

$$C_s = (0.1...0.15) C_i \text{ – for slats.}$$

The figure 2.2. shows a top view of a wing.

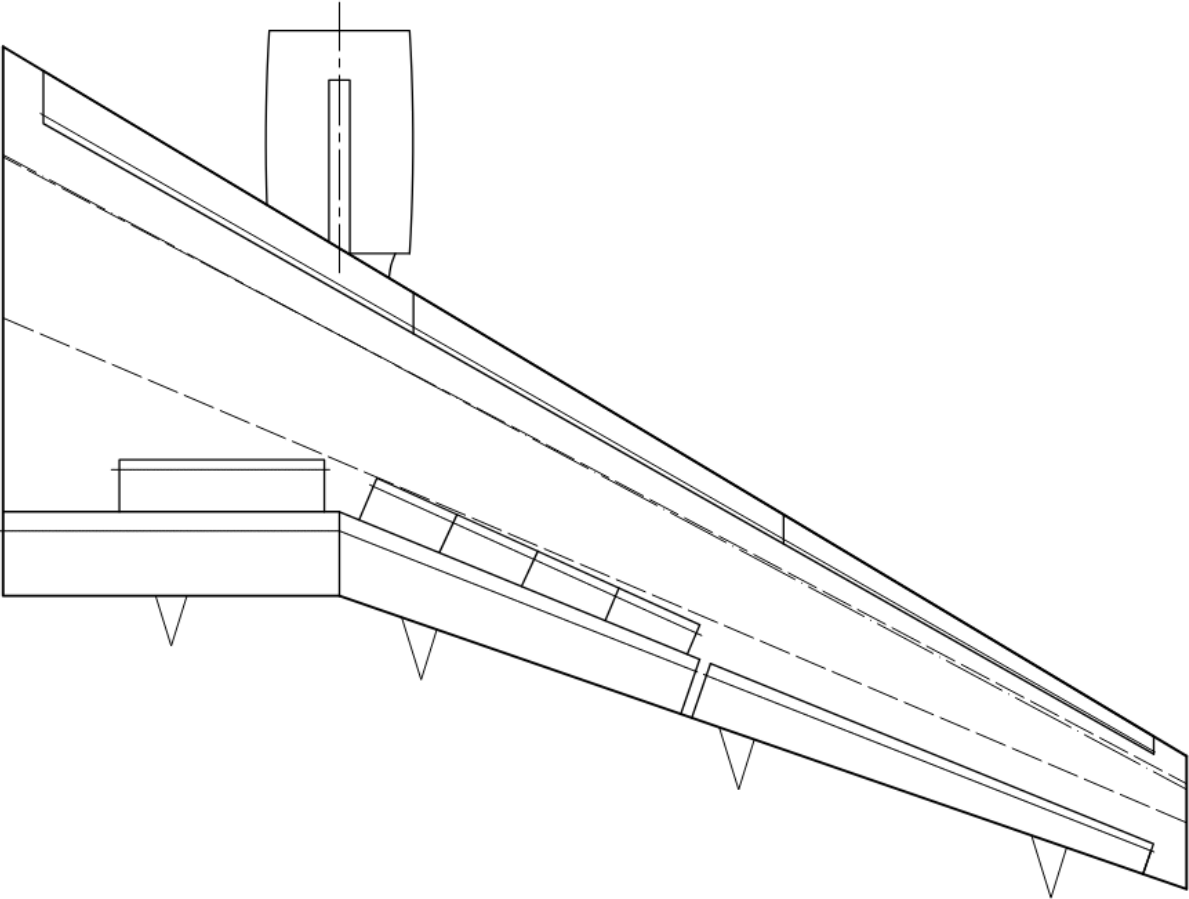


Fig. 2.2. Top view of a wing.

2.1.2. Fuselage layout

The 5.64-meter fuselage cross-section is the widest in its category; giving passengers as much space as possible and delivering a feeling of comfort throughout the aircraft. The unmatched flexibility of this jetliner’s seating arrangements – combined with galley, lavatory and attendant seat location options – allows operators

to customise the cabin to best suit their needs and market requirements. Passenger comfort is further enhanced with large overhead storage for optimal carry-on baggage capacity, while the cabin air system provides draught-free air conditioning – with temperature control in three separate cabin areas.

Seats in economy class are placed according to the scheme 3 + 2 + 3 and also there is business class with seats placed according to 2 + 2 + 2.

Capable of incorporating modern in-flight entertainment options, the airplane continues to represent high quality standards of design and comfort.

The fuselage connects the wing consoles and the tail. The aircraft fuselage is designed to accommodate the crew, equipment, passengers, cargo and other target load.

The fuselage strength set consists of the bulkheads (frames and formers), longerons, stringer and skin. Formers play a key role in defining the fuselage shape and help minimize the length of stringers to prevent instability. These structural components are commonly affixed to longerons, providing support for the aircraft's skin. Longerons are spar-like structures that run lengthwise of the airplane's fuselage or span wise of a wing. The purpose they serve is to transfer loads and stresses from the aircraft's skin to the formers. Within an aircraft fuselage, stringers are affixed to formers and extend longitudinally along the aircraft. Their primary function is to transfer the aerodynamic forces applied to the skin onto the frames and formers.

For passenger aircraft, the layout of the cabin is important. This includes the arrangement of seats, aisles, lavatories, galleys, and other amenities. The cabin layout influences passenger comfort, capacity, and overall interior design.

Fuselage is divided into three parts: front (cockpit compartment), middle (passenger compartment or cargo cabin) and rear part (tail unit).

The cockpit is the forward part of the fuselage and provides space for the crew, including pilots and flight attendants. The cockpit is designed to control and control the aircraft, including control systems, navigation and equipment to ensure the safety and comfort of crew members.

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The middle section of the fuselage contains the passenger compartment, cargo space, and systems such as heating, ventilation and air conditioning. The central part of the fuselage is designed to accommodate passengers, and this is where their seats are located. It also provides space for cargo transportation and various service systems to ensure comfort and safety on board.

In the tail section of the fuselage vertical and horizontal tail surfaces are located, as well as various systems. The tail section is designed to provide stability and controllability of the aircraft in the air.

When determining fuselage parameters, it is crucial to consider the aerodynamic demands related to the streamline and cross-sectional shape. The circular cross-section is deemed the most effective, as it achieves a balance between minimal weight and maximum strength, thus meeting strength requirements and minimizing overall weight—a crucial aspect in aircraft design.

Our focus extends to key geometric parameters, including fuselage diameter, length, fineness ratio, nose and tail unit geometry. The design of the fuselage length takes into account the aircraft's intended purpose, passenger capacity, cabin layout, and factors affecting the aircraft's center of gravity position and landing angle of attack.

1. Length of the aircraft fuselage L_{fus} could be calculated by the formula

$$FR = \frac{L_{fus}}{D_{fus}},$$

$$L_{fus} = FR_f \cdot D_{fus} = 8 \cdot 5.64 = 45.12 \text{ m.}$$

FR – fineness ratio of the fuselage;

D_{fus} – diameter of the fuselage.

2. Length of aircraft fuselage forward part:

$$L_{fwd} = FR_{np} \cdot D_{fus} = 1.18 \cdot 5.64 = 6.66 \text{ m.}$$

3. Length of the fuselage tail part:

$$L_{tail \text{ part}} = FR_{tu} \cdot D_{fus} = 2.2 \cdot 5.64 = 12.41 \text{ m.}$$

4. Cabin width.

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For passenger aircraft fuselage, the size of passenger cabin is important.

The cabin width of passenger aircraft in a place where we have passenger's seats can be found by the formula:

$$B_{cabin} = n_2 b_2 + n_3 b_3 + n_{aisle} b_{aisle} + 2\delta + 2\delta_{wall},$$

n_2 ; n_3 – number of blocks of seats with 2 or 3 seats in a cross section;

b_2 ; b_3 – width of block of 2 seats or 3 seats, mm;

n_{aisle} – number of aisles;

b_{aisle} – aisle width, mm;

δ – distance between external armrests to the decorative panels, mm;

(minimum 50 mm for the 1st class, minimum 30 mm for others classes)

$\delta_{wall} = 80...120$ – width of the wall (fuselage structure, insulation, decorative panels), mm.

For the economic class cabin, I design the passenger seat as 3+3+3 each row.

The appropriate width of economic class cabin:

$$B_{cab} = n_3 b_3 + n_2 b_2 + n_{aisle} b_{aisle} + 2\delta + 2\delta_{wall},$$

$$B_{cab} = 3 \cdot 1440 + 2 \cdot 500 + 2 \cdot 40 + 2 \cdot 120 = 5640 \text{ mm.}$$

For business class, I designed the passenger seat as 2+2+2 each row.

The appropriate width of business class cabin:

$$B_{cab} = n_2 b_2 + n_{aisle} b_{aisle} + 2\delta + 2\delta_{wall}.$$

$$B_{cab} = 3 \cdot 1340 + 2 \cdot 600 + 2 \cdot 90 + 2 \cdot 120 = 5640 \text{ mm.}$$

5. Cabin height.

After the definition of the cabin width we should define the height of the cabin, which is also very important for the comfort.

For wide body planes with number of seats in one row more than 6:

$$H_{cabin} = 0,296 + 0,383 B_{cabin}.$$

Height of the passenger cabin plays an important role in the size of passenger

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cabin mid-section.

Cabin height is:

$$H_{cab} = 0.296 + 0.383B_{cab} = 0.296 + 0.383 \cdot 5.64 = 2.46 \text{ m.}$$

The windows are located in a single row on each side of the fuselage and are elliptical in shape. The choice of ellipse shape is intentional because it helps reduce stress concentrations, a common problem associated with aircraft windows. These windows are located between two bulkheads, and in the project the distance between two adjacent windows is approximately 550 mm.

6. Length of the cabin.

The passenger seats are installed along the length of the passenger cabin with correct seat pitch, which depend on the flight duration and class of the cabin. Seat pitch must be divisible to one inch. (25,4 mm).

Cabin length L_{cab} for typical accommodation with constant seat pitch L_{seat} :

$$L_{cab} = L_1 + (N - 1)L_{seat} + L_2,$$

L_1 – distance from the wall to the back of the seat in first row, mm;

L_2 – distance from the back of the seat in the last row to the wall, mm.

The length of economic passenger cabin:

$$L_{econ} = L_1 + (N - 1)L_{seatpitch} + L_2,$$

$$L_{econ} = 1200 + (25 - 1) \cdot 870 + 300 = 22380 \text{ mm.}$$

The length of business passenger cabin is equal:

$$L_{busi} = L_1 + (N - 1)L_{seatpitch} + L_2,$$

$$L_{busi} = 1200 + (4 - 1) \cdot 960 + 300 = 4380 \text{ mm.}$$

7. Baggage compartment.

Baggage compartments are situated beneath the floor of the passenger cabin, a critical configuration that directly impacts the aircraft's center of gravity during flight.

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9. Lavatories

Number of toilet facilities is determined by the number of passengers and flight duration: with $t > 4:00$ one toilet for 40 passengers, at $t = 2 \dots 4$ hours and 50 passengers $t < 2$ hours to 60 passengers.

$$t = \frac{Range_{flight}}{V_{cruise}} + 0.5 = \frac{6000}{850} + 0.5 = 7.5 \text{ h,}$$

$$N_{lavatory} = \frac{N_{passenger}}{40} = \frac{240}{40} = 6.$$

The number of lavatories I choose according to the original airplane and it is equal 6.

Area of lavatory:

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

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

On my aircraft, 2 galleys and 6 lavatories are designed. Galley and lavatory design are similar to the prototype.

2.1.3. Calculation of basic parameters of tail unit

A critical aspect of the aerodynamic layout is determining the position of the tail unit (TU). To guarantee longitudinal stability during maneuvering flight, it is essential to position the aircraft's center of gravity ahead of the aircraft focus (aerodynamic center). The distance between these points, known as the arm for the aerodynamic moment of the lift force, is expressed relative to the mean value of the wing's aerodynamic chord. This distance plays a pivotal role in establishing the rate of longitudinal stability [1].

$$m_x^{Cy} = x_T - x_F < 0,$$

where m_x^{Cy} – is the moment coefficient; x_T , x_F – center of gravity and focus coordinates.

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Statistic range of static moment coefficient of horizontal tail unit A_{htu} , and vertical tail unit A_{vtu} are given in the table 2.1. with typical arms for HTU and VTU in ratio to mean aerodynamic chord of the wing. Using this table we may find the first approach of geometrical parameters determination.

Table 2.1

Range of TU static moments

Airplane type	A_{htu}	A_{vtu}	L_{htu}/b_{mac} , and L_{vtu}/lw
Large, not maneuverable, with swept wing	0.5..0.6	0.06..0.1	2.0..3.0

Determination of the TU geometrical parameters.

Usually the areas of vertical S_{VTU} and horizontal S_{HTU} of TU is:

$$S_{HTU} = (0.18...0.25)S = 0.2 \cdot 294 = 58.8 \text{ m}^2,$$

$$S_{VTU} = (0.12...0.20)S = 0.15 \cdot 294 = 44.1 \text{ m}^2.$$

Determination of the elevator area and direction.

Altitude elevator area:

$$S_{el} = (0.3...0.4)S_{VTU} = 0.3 \cdot 44.1 = 13.23 \text{ m}^2.$$

Rudder area:

$$S_{rudder} = (0.2...0.22)S_{HTU} = 0.2 \cdot 58.8 = 11.76 \text{ m}^2.$$

Choose the area of aerodynamic balance:

$$M0.75 \geq S_{abel} \approx S_{abbrudder} = (0.18...0.2)S_{controlsurface} = 0.2 \cdot 12.5 = 2.5 \text{ m}^2.$$

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

$$M < 1h_{VTU} = (0.14...0.2)l_{wing} = 0.16 \cdot 51 = 8.15 \text{ m}$$

TU span is related to the following dependence:

$$l_{HTU} = (0.32 \dots 0.5) l_{wing} = 0.4 \cdot 51 = 20.4 \text{ m.}$$

Tapper ratio of horizontal and vertical TU we need to choose:

For planes $M < 1$ $\eta_{htu} = 2 \dots 3$, $\eta_{vtu} = 1 \dots 1.33$.

TU aspect ratio for transonic planes $\lambda_{vtu} = 0.8 \dots 1.5$, $\lambda_{htu} = 3.5 \dots 4.5$.

Root chord of horizontal stabilizer is:

$$b_{0HTU} = \frac{2S_{HTU} \cdot \eta_{HTU}}{(1 + \eta_{HTU}) \cdot l_{HTU}} = \frac{2 \cdot 58.8 \cdot 2.5}{(1 + 2.5) \cdot 20.4} = 4.12 \text{ m.}$$

Tip chord of horizontal stabilizer is:

$$b_{HTU} = \frac{b_{0HTU}}{\eta_{HTU}} = \frac{4.12}{2.5} = 1.6 \text{ m.}$$

Root chord of vertical stabilizer is:

$$b_{0VTU} = \frac{2S_{VTU} \cdot \eta_{VTU}}{(1 + \eta_{VTU}) \cdot h_{VTU}} = \frac{2 \cdot 44.1 \cdot 1.33}{(1 + 1.33) \cdot 8.15} = 6.18 \text{ m.}$$

Tip chord of vertical stabilizer is:

$$b_{VTU} = \frac{b_{0VTU}}{\eta_{VTU}} = \frac{7.05}{1.33} = 4.65 \text{ m.}$$

2.1.4. Landing gear design

During the initial phase of design, when the precise center-of-gravity position of the aircraft is not yet established, and a comprehensive overview drawing of the airplane is unavailable, only certain landing gear parameters may be ascertained.

The distance from the center of gravity to the main landing gear:

$$B_m = (0.15 \dots 0.20) b_{MAC} = 0.18 \cdot 6.3753 = 1.15 \text{ m.}$$

When the nose gear lift distance during takeoff is substantial, it poses challenges, while a smaller distance may lead to the risk of the airplane's tail striking the ground, particularly if the rear of the aircraft is loaded more. Additionally, inadequate loading on the nose landing gear could result in instability during the aircraft's ground run,

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especially on slippery runways and in crosswind conditions. Landing gear wheel base comes from the expression:

$$B = (0.3...0.4)l_f = 0.35 \cdot 45.12 = 15.8 \text{ m.}$$

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

The distance from the center of gravity to the nose landing gear will be equal:

$$Bn = B - Bm = 15.8 - 1.15 = 14.65 \text{ m.}$$

Wheel track is:

$$T = (0.7...1.2)B \leq 12 = 0.7 \cdot 15.8 = 11.06 \text{ m.}$$

To avoid the risk of side nose-over, it is imperative that the value of T is greater than 2H, where H represents the distance from the runway to the center of gravity. The selection of landing gear wheels depends on their size and the load they bear during takeoff. For the front support we consider dynamic loading also.

The choice of tire type and the pressure within it are dictated by the characteristics of the runway surface to be utilized. Brakes are typically installed on the main wheels, and occasionally, on the front wheel as well.

The load on the wheel is determined by next formulas.

Nose wheel load is equal:

$$F_n = \frac{9.81 \cdot Bm \cdot K_g \cdot m_0}{B \cdot z} = \frac{1.15 \cdot 113734 \cdot 1.75 \cdot 9.81}{15.8 \cdot 2} = 71057 \text{ N.}$$

Main wheel load is equal:

$$F_m = \frac{9.81 \cdot (B - Bm) \cdot K_g \cdot m_0}{B \cdot z \cdot n} = \frac{(15.8 - 1.15) \cdot 113734 \cdot 9.81 \cdot 1.75}{15.8 \cdot 2 \cdot 4} = 226301.8 \text{ N,}$$

where n , and z – is the quantity of the supports and wheels on the one leg.

$K_g = 1.5...2.0$ – dynamics coefficient.

Pneumatic wheels were selected from the Dunlop part reference guide (table 2.2).

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Table 2.2

Aviation tires for designing aircraft [2]

Size	Ply Rating	TT or TL	Rated Speed (mph)	Tire pressure (psi)
Nose landing gear tires				
40 x 14 R16	22	TL	225	145
Main landing gear tires				
46 x 17 R20	32	TL	225	178

2.1.5. Choice and description of power plant

The General Electric CF6, US military designations F103 and F138, is a family of high-bypass turbofan engines produced by GE Aviation. Based on the TF39, the first high-power high-bypass jet engine, the CF6 powers a wide variety of civilian airliners. Characteristic of engine are at table 2.3.

Table 2.3

Characteristic of engine

Name	CF6-80C2
Type	Dual rotor, axial flow, high bypass ratio turbofan, annular combustor
Compressor	Fan & 4LP + 14HP
Turbine	2HP + 5LP
Length	168 in (427 cm)
Overall diameter	106-111 in (269-282 cm)
Fan diameter	93 in (236 cm)
Blade Count	38
Bypass ratio	5-5.31
Weight	9,480-9,860 lb, 4,300-4,470 kg

2.2. Center of gravity calculation

2.2.1. Trim-sheet of the equipped wing

The equipped wing's mass encompasses the weight of its structure, the equipment housed within the wing, and the fuel it carries. Whether mounted on the wing or fuselage, the main landing gear and front gear are accounted for in the mass registry of the equipped wing. This registry details the names of objects, their masses,

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Ending of the table 2.5

7	aero navigation equipment	0,004	618,804	2	1237,608
8	Flight control system 70%	0,003	508,966	22,56	11482,28
9	hydraulic system 30%	0,004	640,462	31,584	20228,356
10	electrical equipment 90%	0,026	4037,696	22,56	91090,424
11	lining and insulation	0,007	1021,027	22,56	23034,36
12	Anti-ice system, 20%	0,004	612,616	36,096	22112,986
13	air-conditioning system, 40%	0,008	1225,232	22,56	27641,232
Passenger aircraft					
Passenger eq+ Non typical eq+ Additional equipment+ Service equipment					
14	passenger seats (economic class)	0,0098	1528,762	23,3	35620,166
15	passenger seats (business)	0,001	168	9	1512
16	seats of flight attendance	0,0002	35	21,19	741,65
17	seats of pilot	0,00064	100	2,6	260
18	Emergency equipment	0,00065	102	8,1	826,2
Furnishing (Lavatory, Galley/buffet)					
19	lavatory 1, lavatory 2, galley 1	0,0076	1186,811	5,14	6100,209
20	lavatory 3, lavatory 4	0,0076	1186,811	17,66	20959,084
21	lavatory 5, lavatory 6, galley 2	0,0076	1186,811	35,91	42618,388
22	Operational items	0,0162	2507,7	26	65200,283
23	additional equipment	0,0079	1223,684	5	6118,424
	Equipped fuselage without payload	0,2154	33323,358	22,382	745866,54
Payload					
24	Passengers(economy)	0,1075	16632	23,3	387525,6
25	Passengers(business)	0,0119	1848	9	16632
26	on board meal	0,0023	360	35,91	12927,6
27	baggage	0,0465	7200	19,02	136944
28	cargo, mail	0,0233	3620	19,02	68852,4
29	flight attend	0,0027	420	21,19	8899,8
30	crew	0,0009	154	2,6	400,4
	Total	0,4108	63557,358	21,6819	1378048,3

The coordinates of the fuselage devices are indicated in the appendix C according to Table 2.5.

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2.2.3. Calculation of center of gravity positioning variants

The list of mass objects for center of gravity variant calculation given in Table 2.6 and Center of gravity calculation options given in table 2.7, completes on the base of both previous tables.

Table 2.6

Calculation of C.G. positioning variants

Name	Mass, kg	Coordinates	Moment
Object	m_i	C.G. M	kgm
equipped wing (without fuel and landing gear)	35253,26	20,21	712575,02
Nose landing gear (extended)	840,49	7,79	6550,47
main landing gear (extended)	4762,78	23,59	112371,25
fuel reserve	6443,30	22,96	147912,94
fuel for flight	46937,83	22,96	1077509,40
equipped fuselage (without payload)	33323,36	22,38	745866,54
Passengers(economy)	16632	23,30	387525,60
Passengers(bussiness)	1848	9,00	16632,00
on board meal	360	35,91	12927,60
baggage	7200	19,02	136944,00
cargo, mail	3620	19,02	68852,40
flight attend	420	21,19	8899,80
crew	154	2,60	400,40
Nose landing gear (retracted)	840,490	6,39	5368,91
main landing gear (retracted)	4762,779	23,19	110438,55

Conclusions to the project part

In this part, the geometric characteristics of the aircraft and the alignment of the aircraft were determined. The geometric parameters of the wing and its high-lift devices were determined, the load on the landing gear was determined, and the parameters of the engines were specified. The location of passenger seats, lavatories, doors, galleys, etc. was also determined and calculated.

The extreme forward position of the center of gravity of the equipped aircraft is 18.4% of the main aerodynamic chord in flight. The extreme aft position of the center of gravity of the aircraft is 26.3% of the main aerodynamic chord. Between these values, the plane is in the center.

The layout of the aircraft was justified and developed in accordance with the issued technical task and parameters. Based on the prototype, calculations and drawings were made.

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3. CONCEPTUAL DESIGN OF THE PASSENGER SEAT HEIGHT ADJUSTMENT

3.1. Requirements to the passenger's comfort on board

Air transportation is concerned about flight safety and reliability. Airlines compete to attract passengers by implementing new designs of the passenger cabin, services, and prices, of course. Some articles demonstrate that improving the design of the salon can increase the number of passengers who choose the same aircraft for their next flight. The passenger comfort in the cabin will depend on the freedom of passengers to change their body position, especially during long flight. This freedom could be provided by the movable seat design, allowing for control over the height position. As part of the diploma thesis, a seat height adjustment mechanism has been designed.

The flight should be safe, inexpensive, fast and comfortable. The seats and their placement must comply with these characteristics. The seating arrangement on the aircraft is designed to utilize space as efficiently as possible and provide the optimal number of seats to carry passengers.

Passenger seats on an airplane play an important role in ensuring safety, comfort and efficient use of space on board. The seats are designed to provide restraint for passengers in the event of turbulence or an accident. During the flight, passengers can remain in the seats for a long time, so the seats are designed to be comfortable.

The seats should be light and at the same time durable, fire-resistant and comfortable. Alloys, metals, composites, plastics, and various coatings are used in airplane passenger seats. The normal design is an aluminum frame with polyurethane foam blocks attached to it. In some cases, a layer of fire-resistant fabric, such as Kevlar or Nomex, goes over this, with a layer of fabric or leather on top.

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<i>Head of dep.</i>	<i>Yutskevich S.S.</i>							

Physical well-being is a manifestation of the physical impact on the passenger and his body. Physical well-being depends on how energetic the passage feels and what support the body receives.

Proxemics is about personal space in relation to the people around. In the airplane cabin, this parameter characterizes concern for a certain level of passenger autonomy, comfort in carrying out personal affairs, and immediate space and privacy.

Satisfaction shows how the environment helps the passenger to achieve certain goals. This refers to how passengers perceive the availability of user features (e.g. seat control, seat recline, entertainment unit) and their quality. In other words, satisfaction characterizes the passenger's expectations and how well the reality meets his expectations [6].

Pleasure is manifested when the passenger receives more than expected, associating comfort with positive surprises and with a pleasant atmosphere in the cabin and stimulation. Social is about in-flight social interactions, whether they are tolerable for passengers and how responsive they are. Aesthetics describes the passenger's impression of the interior's style and cleanliness [6].

An association describes an experience that evokes a desired pleasant memory or symbolizes a pleasant experience.

The seat is the central determinant of passenger comfort, which must satisfy 7 out of 8 comfort characteristics, in addition to satisfaction. A person's height is the main factor contributing to the physical well-being of the passenger. The following table 3.1 shows how the chair itself should satisfy all aspects of comfort.

Table 3.1

Description of the characteristics of comfort [6]

Characteristics of comfort	Theme Common seat descriptions Concern
Physical wellbeing	There is no need to fold the pillow to fit it under the curve of the backrest, because the backrest corresponds to the backrest. Does not bother with pain or cramps. Easy to move.
Peace of mind	Safe, worry-free, not cramped, spacious, can store personal belongings, no irritation or fuss. Head and neck support (headrest ear) to prevent the head from falling during sleep. Soft recline and comfortable sleeping position.
Proxemics	Armrests are available, which allow you to lean back freely and control your position with peace of mind. Lack of physical contact with neighbors, sufficient space under the armrests, lack of feeling of compression by neighbors, personal space similar to a cocoon.
Aesthetics	Appear new/refurbished and clean (no food residue or torn covers). Good seat covers, bright colors, pleasant to the touch.
Satisfaction	Works well, solid and functional construction (no broken parts, malfunctions). The tilting system is well made and logical and allows food to arrive comfortably. The buttons on the seats are well located, the radio buttons cannot be pressed accidentally.
Association	The feeling is as if you are sitting in a hotel lobby or in a car.
Pleasure	It's nice that the seats seem wider than usual. Comfortable, attractive and modern (wooden details).
Social	You can put your hands on the low armrests.

To increase the level of passenger comfort, I present a seat height adjustment mechanism designed for business class seats.

The design of non-adjustable seats does not consider the unique needs of its users, and the users are the ones who adjust to the seat. For instance, if a seat is too high, your feet may not touch the ground. This can lead to pressure points on your legs and lower back pain. On the other hand, if a seat is too low, you may find it uncomfortable to position your legs.

Unlike fixed seats, height-adjustable ergonomic seats are designed to adjust to suit the user, thus ensuring their comfort and well-being.

Height adjustable seats help maintain correct posture while sitting, as the seat can be adjusted to the height and position that provides the most support to the body. Feet on the floor to keep your knees at the right angle, ample lumbar support to comfortably arch your back, a headrest to relax your neck and head, and armrests to comfortably support your arms.

This ergonomic seat can be customized to fit different body shapes, both in width and height. This feature ensures that the seat provides the right comfort and support, and reduces the risk of body pain and other health problems. The seat can also be easily adjusted using the buttons and handles during the flight.

Height adjustable seats provide a comfortable and natural posture throughout the flight and solve the problem with pressure points. Pressure points can block blood circulation in different parts of the body, firstly in the legs, causing discomfort, numbness and even pain. Ergonomic seats help prevent this from happening.

The ergonomic design of the passenger seat means how the seat is adapted with the human body and the environment. For each country the parameters of human body are different, and the statistical data demonstrate the different percentiles of human body for each country (region). The key suggestions with regards to the seat design through anthropometric parameters are: seat height, seat width, seat depth, armrest height/width/depth, seat pitch, backrest height/width/lumber height, headrest width/height/. These parameters are standard for the typical seats or block of seats in economy class.

At the presented work there is a conceptual design of the passenger seat for the business class with the possibility to control the height of the seat cushion. It can be done by the height adjustment control mechanism – gas lift, which is installed between the seat cushion frame and the platform of the seat attachment to the floor.

3.2. Conceptual design of seat height adjustment mechanism

The main components of the gas lift are shown at fig. 3.2:

- piston – moves and changes the height of the seat;

So we found the pressure at the top of the cylinder that will hold the person, but we also need to find the pressure at the bottom of the cylinder. The pressure from below must be higher than the pressure from above. At the same time, the pressure from below should become lower than the pressure from above when a person begins to press on the gas lift weighing 30 kilograms. So let's find the difference in pressure for a weight difference of 30 kilograms:

$$P = \frac{F}{S} = \frac{1617}{0,000308} = 5250000 Pa \approx 52 \text{ atm.}$$

Without a passenger, the pressure in the upper part of the cylinder = 43 atm, in the lower part = 52 atm.

3.4. Step-by-step development of a gas lift

The design of the gas lift was performed by the SolidWorks. The main stages of the design process are:

1. Create a sketch of the hydraulic cylinder holder and extrude it, fig. 3.5. All gas lift components are placed inside it.

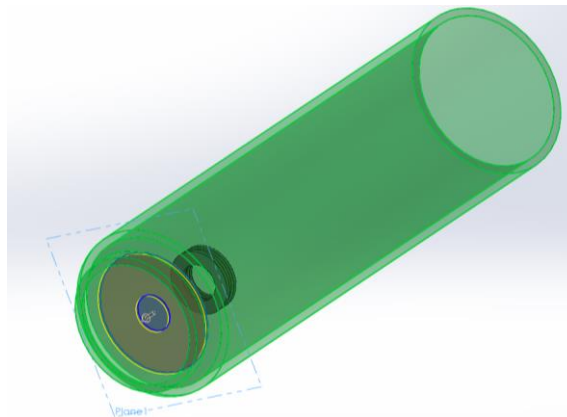


Fig. 3.5. The model of the cylinder holder.

2. Create a sketch of the rubber gasket and extrude it, fig. 3.6.

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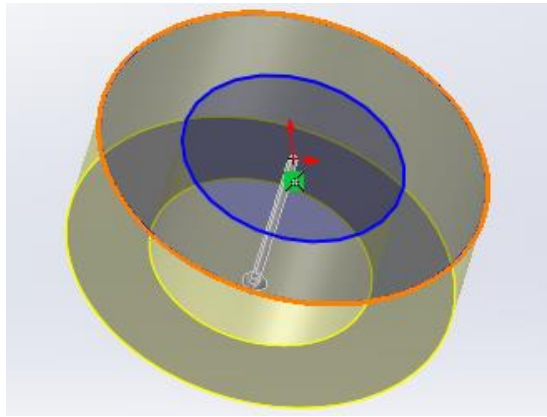


Fig. 3.6. Rubber gasket model.

3. Create a sketch of the rod and extrude it, fig. 3.7. A piston is placed on this rod. The piston will move freely inside the cylinder with the help of changing pressures and raise or lower the seat.

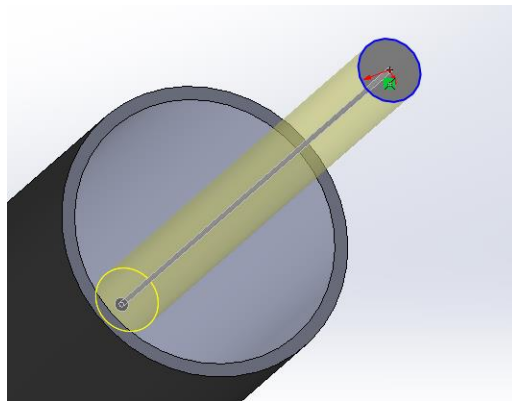


Fig. 3.7. Rod model.

4. Create a gas lift clip surface and make it thick. Make necessary cut, fig. 3.7. It closes all parts of the gas lift. it tightly presses the gas lift cylinder and the piston rod.

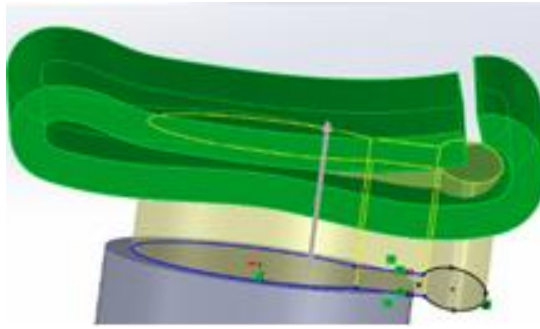


Fig. 3.7. Gas lift clip model.

5. Combine necessary parts of rod and locate details where needed, fig. 3.8. if you remove the gas lift clip, you can remove the gas lift from the hydraulic cylinder holder, but the gas lift itself cannot be disassembled by hand because there is gas under pressure inside.

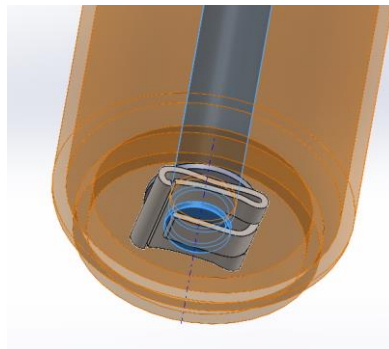


Fig. 3.8. Rod model.

6. Create a sketch of the piston and extrude it. Create sealing ring, fig. 3.9. The seal and sealing rings prevent gas from leaking out.

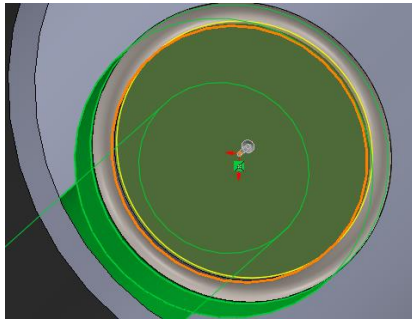


Fig. 3.9. Piston model.

7. Create a sketch of the cylinder and extrude it, fig. 3.10. A piston moves in the cylinder.

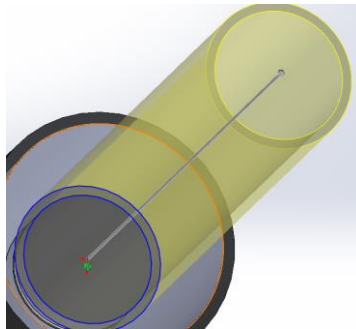


Fig. 3.10. Cylinder model.

8. Create a sketch of the hydraulic cylinder and extrude it, fig. 3.11. There is gas in the cylinder.

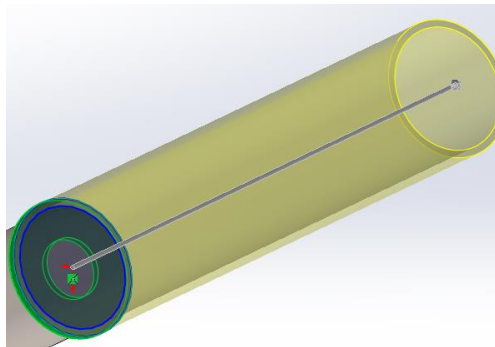


Fig. 3.11. Hydraulic cylinder model.

9. Combine all parts of piston rod, fig. 3.12. The piston itself is inside the cylinder, the cylinder is inside the hydraulic cylinder and the hydraulic cylinder is inside the hydraulic cylinder holder.

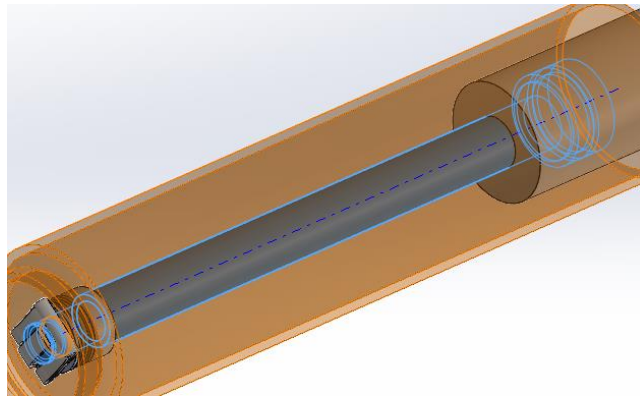


Fig. 3.12. Piston rod model.

10. Create a sketch of the seak and extrude it, fig. 3.13.

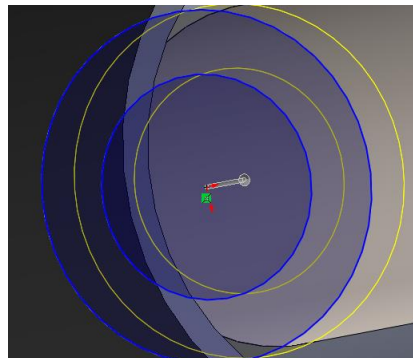


Fig. 3.13. Seak model.

11. Create a sketch of the internal holder and extrude it. Create sealing ring, fig. 3.14. It closes the gas inside and acts as a stopper for the piston. They are located in all places where gas cannot leak out.

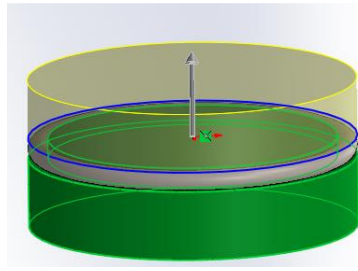


Fig. 3.14. Internal holder model.

12. Create a sketch of the button and extrude it, fig. 3.15. The button system has a valve that opens the gas between the cylinders when a person presses the button.

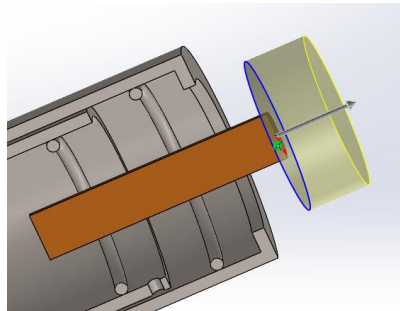


Fig. 3.15. Button model.

13. Cut a hole for gas transfer, fig. 3.16.

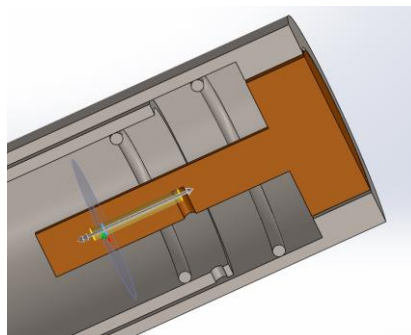


Fig. 3.16. Button with valve model.

14. Smooth the corners, fig. 3.17.

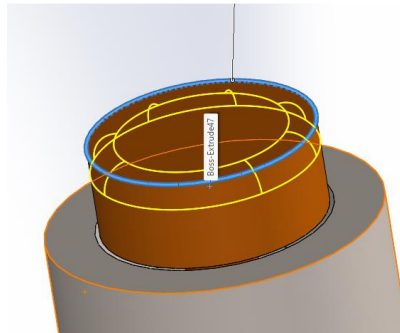


Fig. 3.17. Button model.

15. Create a level arm, fig. 3.18. When a person lifts the handle, a button is pressed and the valve opens.

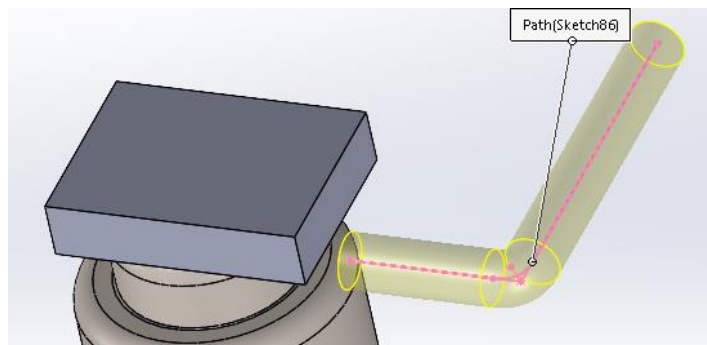


Fig. 3.18. Level arm model.

16. Combine all parts of piastra, fig. 3.19. Piastra fastens the gas lift to the seat. The piastra must bear both longitudinal and transverse loads so that the seat does not break.

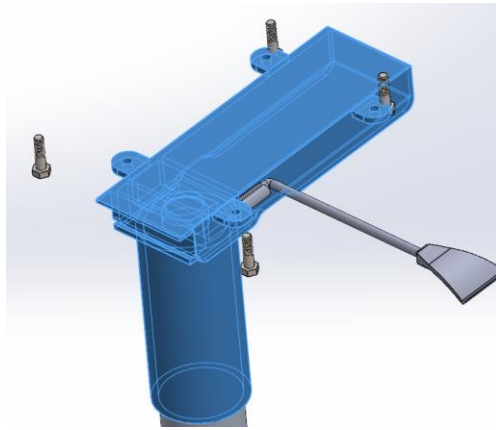


Fig. 3.19. Piastra model.

17. Create a sketch of the all parts of the floor fixing and extrude it. Copy repeating bodies, fig. 3.20.

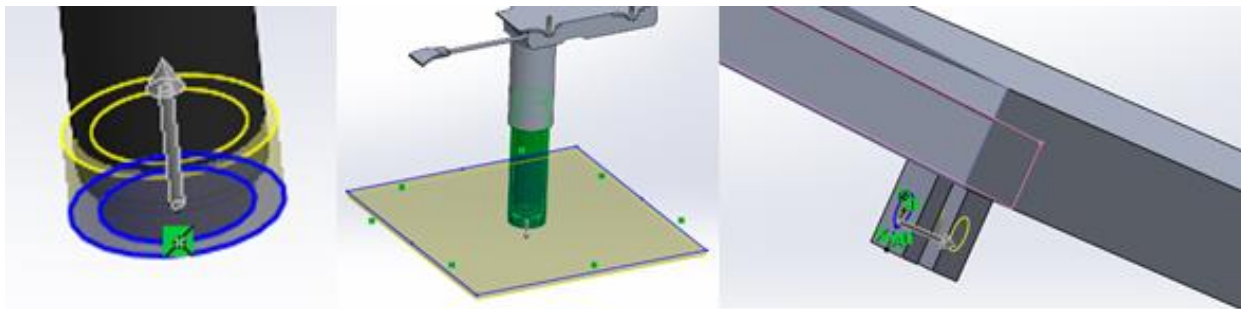


Fig. 3.20. Floor fixing model.

3.5. Strength calculation

Calculation of the strength of all components that will be loaded during operation. The strength calculation will be carried out using the SolidWorks Simulation software. SolidWorks Simulation use Finite Element Analysis to predict a product's physical behavior by virtually testing CAD models.

A strength test is needed to find out whether the structure can withstand an overload in the event of an emergency. According to CS 25.562 "Emergency landing dynamic conditions", the seat must withstand an overload of 16 g along the fuselage and 14 g downward. In addition to the overloads themselves, the weight of the seat

itself, the average weight of the passenger (77 kg) and the safety factor are also taken into account during the strength test.

The system is designed in such a way that the gas lift itself perceives only compression loads (fig. 3.21). All bending loads will be absorbed by the outer cylinders.

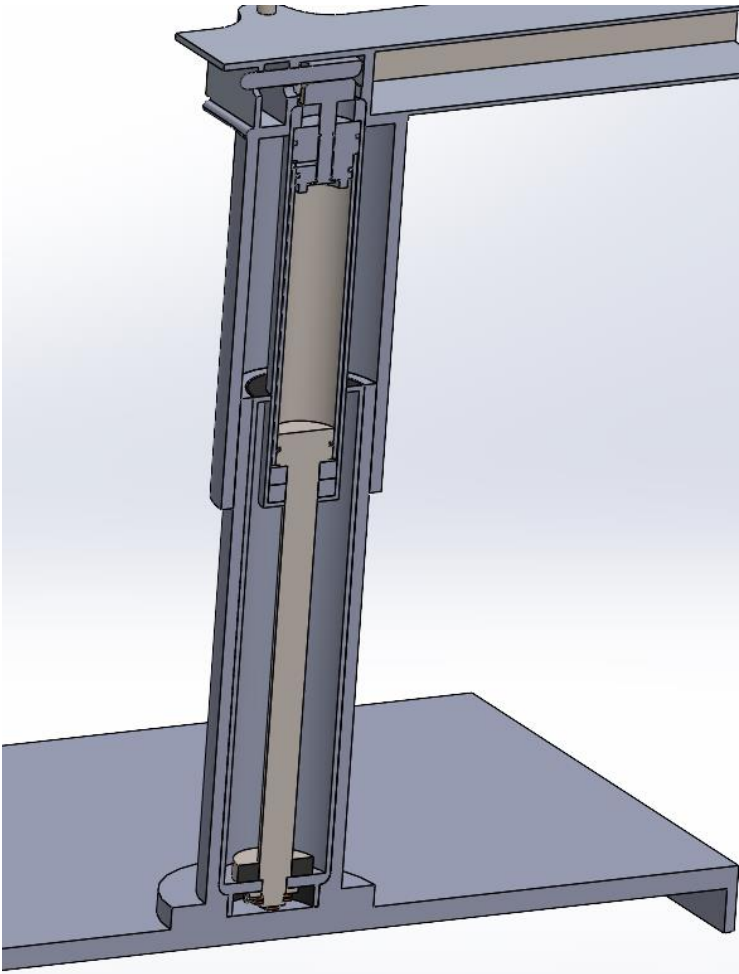


Fig. 3.21. Gas lift in section.

Let's load the platform with attachment to the floor. First, let's apply the load downwards (fig. 3.22).

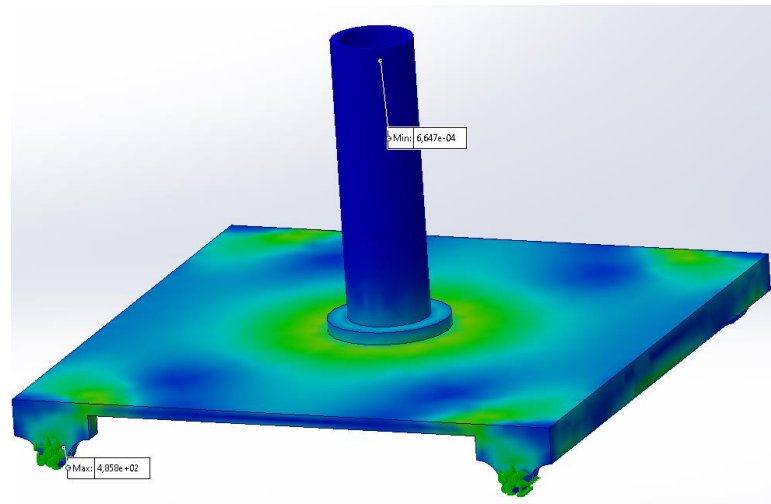


Fig. 3.22. The platform is loaded vertically.

We can see the highest stress and it is 485 MPa. We look at the yield stress of the selected material (fig. 3.24). We chose aluminum. It is equal to 505 MPa. A factor of safety has already been included in the stress parameter we put our body through, so we can compare the maximum stress and the yield stress as one to the other.

Property	Value	Units
Elastic Modulus	72000	N/mm ²
Poisson's Ratio	0.33	N/A
Shear Modulus	26900	N/mm ²
Mass Density	2810	kg/m ³
Tensile Strength	570	N/mm ²
Compressive Strength		N/mm ²
Yield Strength	505	N/mm ²
Thermal Expansion Coefficient	2.36e-05	/K
Thermal Conductivity	130	W/(m-K)

Fig. 3.23. Material characteristics.

The same check is carried out with all components that must withstand the load (fig. 3.26, 3.27, 3.28).

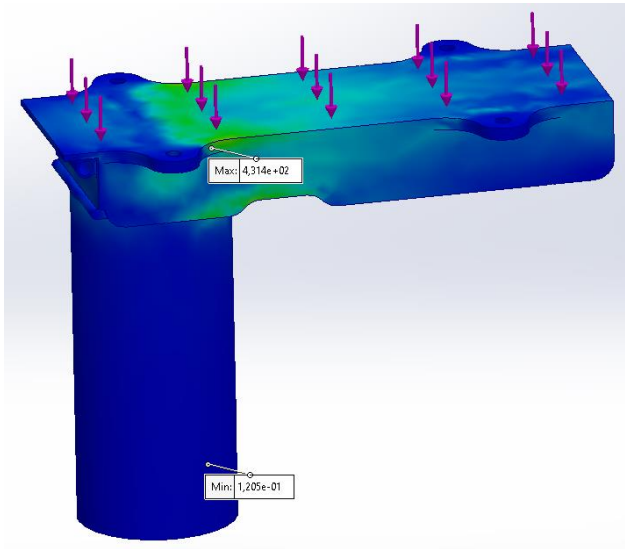


Fig. 3.26. The piastra is loaded vertically.

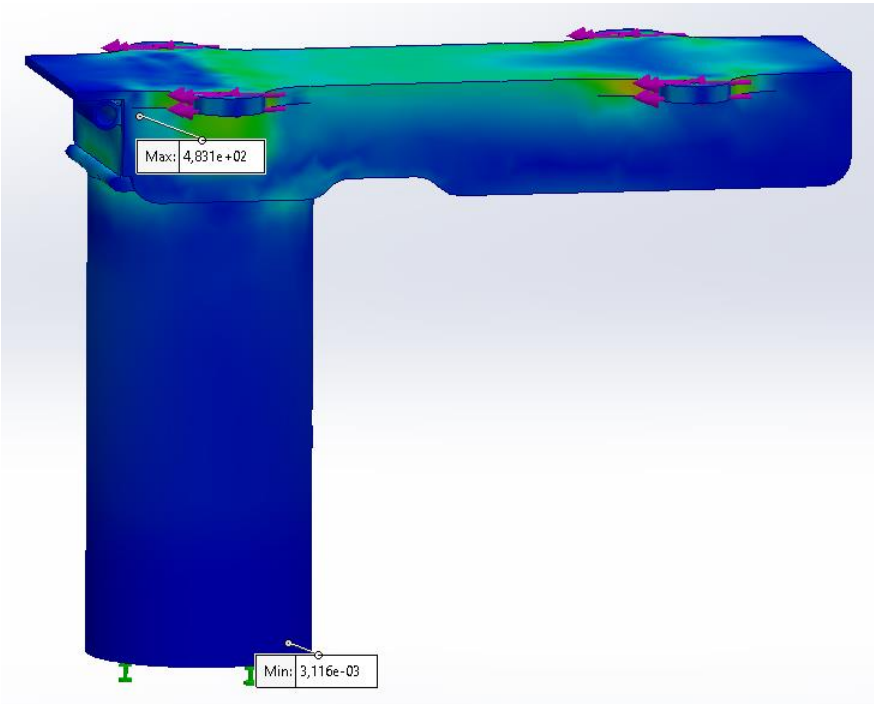
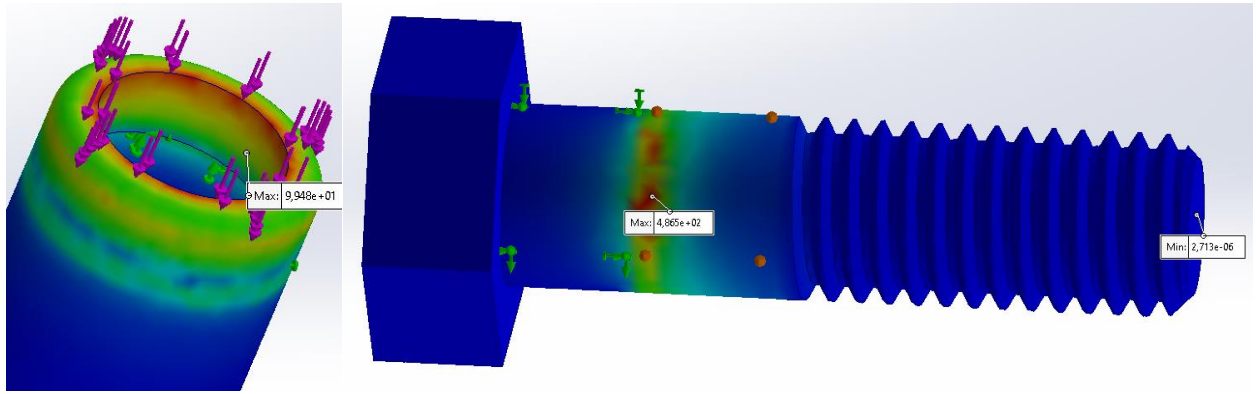
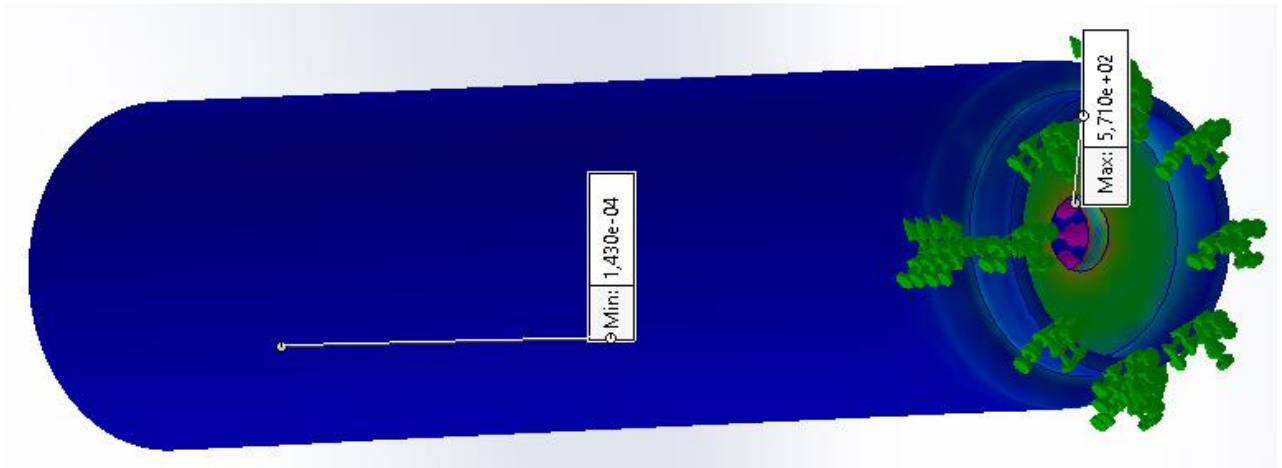


Fig. 3.27. The piastra is loaded horizontally.

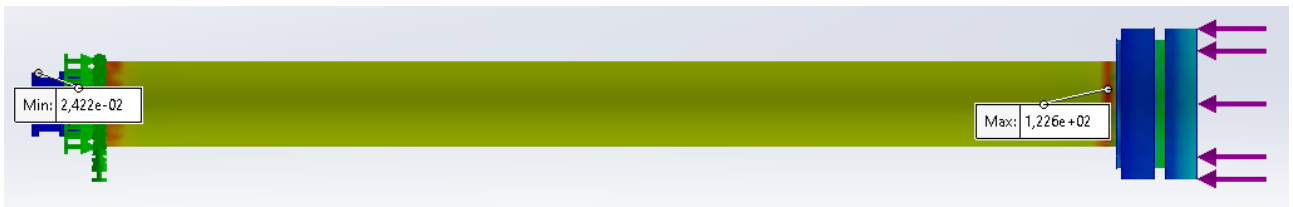


a

b



c



d

a – hydraulic cylinder loaded horizontally; *b* – loaded bolt; *c* – cylindrical holder loaded horizontally; *d* – piston rod loaded horizontally

Fig. 3.28. The loaded elements.

The appearance of a business-class seat with an installed height adjustment mechanism will look like in figure 3.29.



Fig. 3.29. General view of the passenger seat with built-in gas lift.

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Conclusions to the special part

In summary, if the seats of airplane passengers are equipped with seat adjustment mechanisms, it will increase the comfort level of passengers, reduce fatigue from long sitting, improve people's mood and pleasantly surprise them. People with disabilities will find it easier to use chairs that can be adjusted in height, which will provide them with greater comfort and safety.

Accurate calculations and strength measurements have shown that the gas lift design can withstand all loads, which means that the installation of the chair adjustment mechanism is absolutely safe.

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GENERAL CONCLUSIONS

1. During this designing work I've got the next results:

- preliminary design of the long-range passenger aircraft with 240 passengers and 2 classes: 216 at economy class and 24 at business class;
- the center of gravity of the airplane calculations: the most forward center of gravity position is 0.182 from leading edge of mean aerodynamic chord, the most aft center of gravity is 0.27;
- the calculation of the main geometrical parameters of the landing gear: wheel truck – 8.13 m, wheelbase – 15.26;
- the choose of the wheels, which satisfy the requirements: nose LG tire for designed aircraft – 40x14, main LG tire for designed aircraft – 46x17;
- the design of nose landing gear;
- the chosen low-wing design with two engines located under the wing helps reduce aerodynamic drag and increase efficiency, ensures a more uniform distribution of weight along the length of the aircraft, and increases resistance to cross winds;
- the installation of CF6-80C2 turbofan engine provides high cruising speed and good thrust-to-weight ratio;

2. The centering of the plane is in the typical range for the planes of the mid and long-range category.

3. A model of the passenger seat height adjustment mechanism for business class has been created to increase passenger comfort.

4. An analysis of the strength of the seat adjustment mechanism was carried out.

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<i>Checked by</i>	<i>Maslak T.P.</i>				Q	63	72
<i>St. control</i>	<i>Krasnopolsky V.S.</i>				<i>404 ASF 134</i>		
<i>Head of dep.</i>	<i>Yutskevich S.S.</i>						
<i>General conclusions</i>							

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<i>Checked by</i>	<i>Maslak T. P.</i>					Q	64	72
<i>St. control</i>	<i>Krasnopolsky V.S.</i>				<i>404 ASF 134</i>			
<i>Head of dep.</i>	<i>Yutskevich S.S.</i>							

Appendix A

INITIAL DATA AND SELECTED PARAMETERS

Passenger Number	240
Flight Crew Number	2
Flight Attendant or Load Master Number	7
Mass of Operational Items	2507.89 kg
Payload Mass	30240 kg
Cruising Speed	850 km/h
Cruising Mach Number	0.7870
Design Altitude	10.00 km
Flight Range with Maximum Payload	6000 km
Runway Length for the Base Aerodrome	2.95
Engine Number	2
Thrust-to-weight Ratio in N/kg	2.8000
Pressure Ratio	28.30
Assumed Bypass Ratio	5.15
Optimal Bypass Ratio	5.00
Fuel-to-weight Ratio	0.3090
Aspect Ratio	8.80
Taper Ratio	3.53
Mean Thickness Ratio	0.118
Wing Sweepback at Quarter Chord	28.0 degree
High-lift Device Coefficient	0.970
Relative Area of Wing Extensions	0.064
Wing Airfoil Type	supercritical
Winglets	not used
Spoilers	installed
Fuselage Diameter	5.64 m
Fineness Ratio	8
Horizontal Tail Sweep Angle	34.0 degree
Vertical Tail Sweep Angle	40.0 degree

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point	0.44693
--	---------

Induce Drag Coefficient 0.00914

ESTIMATION OF THE COEFFICIENT $D_m = M_{critical} - M_{cruise}$

Cruising Mach Number 0.78701

Wave Drag Mach Number 0.79492

Calculated Parameter D_m 0.00791

Wing Loading in kPa (for Gross Wing Area):

At Takeoff 6.271

At Middle of Cruising Flight 5.148

At the Beginning of Cruising Flight 6.054

Drag Coefficient of the Fuselage and Nacelles 0.01223

Drag Coefficient of the Wing and Tail Unit 0.00916

Drag Coefficient of the Airplane:

At the Beginning of Cruising Flight 0.03317

At Middle of Cruising Flight 0.03156

Mean Lift Coefficient for the Ceiling Flight 0.44693

Mean Lift-to-drag Ratio 14.16147

Landing Lift Coefficient 1.534

Landing Lift Coefficient (at Stall Speed) 2.300

Takeoff Lift Coefficient (at Stall Speed) 1.917

Lift-off Lift Coefficient 1.399

Thrust-to-weight Ratio at the Beginning of Cruising Flight 0.631

Start Thrust-to-weight Ratio for Cruising Flight 2.383

Start Thrust-to-weight Ratio for Safe Takeoff 3.150

Design Thrust-to-weight Ratio 3.276

Ratio $D_r = R_{cruise} / R_{takeoff}$ 0.756

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

Takeoff 36.9050

Cruising Flight 59.7262

Mean cruising for Given Range 65.5428

FUEL WEIGHT FRACTIONS:

Fuel Reserve 0.04165

Block Fuel 0.30341

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.09680
Horizontal Tail	0.00925
Vertical Tail	0.00924
Landing Gear	0.03622
Power Plant	0.09859
Fuselage	0.07207
Equipment and Flight Control	0.11318
Additional Equipment	0.00791
Operational Items	0.01621
Fuel	0.32506
Payload	0.19547

Airplane Takeoff Weight	154701 kg
Takeoff Thrust Required of the Engine	253.40 kN

Air Conditioning and Anti-icing Equipment Weight Fraction	0.0198
Passenger Equipment Weight Fraction (or Cargo Cabin Equipment)	0.0125
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.0066
Furnishing Equipment Weight Fraction	0.0121
Flight Control Weight Fraction	0.0047
Hydraulic System Weight Fraction	0.0138
Electrical Equipment Weight Fraction	0.0290
Radar Weight Fraction	0.0026
Navigation Equipment Weight Fraction	0.0040
Radio Communication Equipment Weight Fraction	0.0020
Instrument Equipment Weight Fraction	0.0046
Fuel System Weight Fraction	0.0106

Additional Equipment:	
Equipment for Container Loading	0.0062
No typical Equipment Weight Fraction (Build-in Test Equipment for Fault Diagnosis, Additional Equipment of Passenger Cabin)	0.0017

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed	304.73 km/h
Acceleration during Takeoff Run	2.64 m/s ²
Airplane Takeoff Run Distance	1353 m
Airborne Takeoff Distance	578 m
Takeoff Distance	1932 m

CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed	289.48 km/h
Mean Acceleration for Continued Takeoff on Wet Runway	0.44 m/s ²
Takeoff Run Distance for Continued Takeoff on Wet Runway	2010.45 m
Continued Takeoff Distance	2588.83 m
Runway Length Required for Rejected Takeoff	2680.24 m

LANDING DISTANCE PARAMETERS

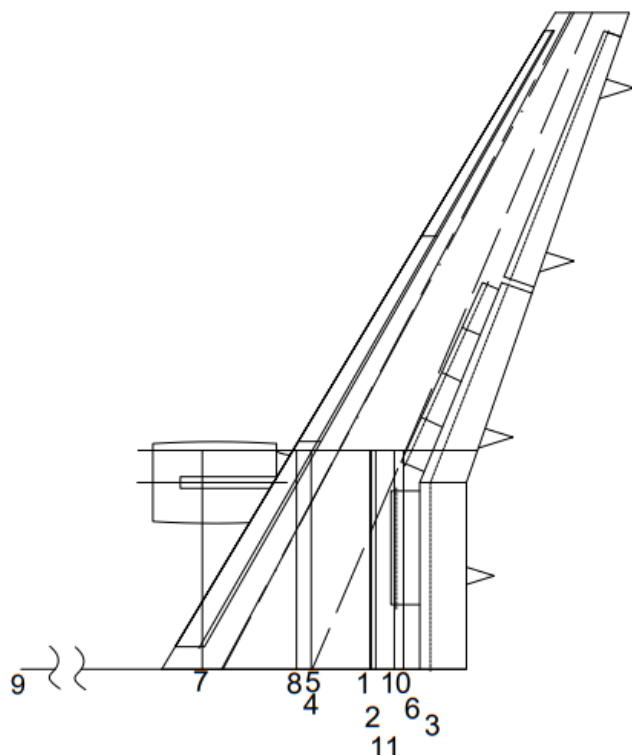
Airplane Maximum Landing Weight	113734 kg
Time for Descent from Flight Level till Aerodrome	20.4 min
Traffic Circuit Flight	
Descent Distance	48.10 km
Approach Speed	268.37 km/h
Mean Vertical Speed	2.13 m/s
Airborne Landing Distance	524 m
Landing Speed	253.37 km/h
Landing run distance	864 m
Landing Distance	1388 m
Runway Length Required for Regular Aerodrome	2319 m
Runway Length Required for Alternate Aerodrome	1971 m

ECONOMICAL EFFICIENCY

Maximum Take Off Weight to Payload	2.3102	
Empty Loaded Aircraft Weight per Passenger	291.08	kg/Pas
Relative Full-Load Performance of the Aircraft	459.46	km/h
Aircraft Performance at Maximum Payload	24656.1	
kg*km/h		
Average Burn of fuel per hour	6378.435	kg/h
Average Burn of fuel per kilometer	7.82	kg/km
Average burn of 1000 kg of fuel per 1 km	258.696	
g/(t*km)		
Average burn of 1000 kg of fuel per 1 km per 1 passenger	28.7609	
g/(Pas*km)		
Costs per gross-tone-kilometer	0.4152	\$(t*km)

Appendix B

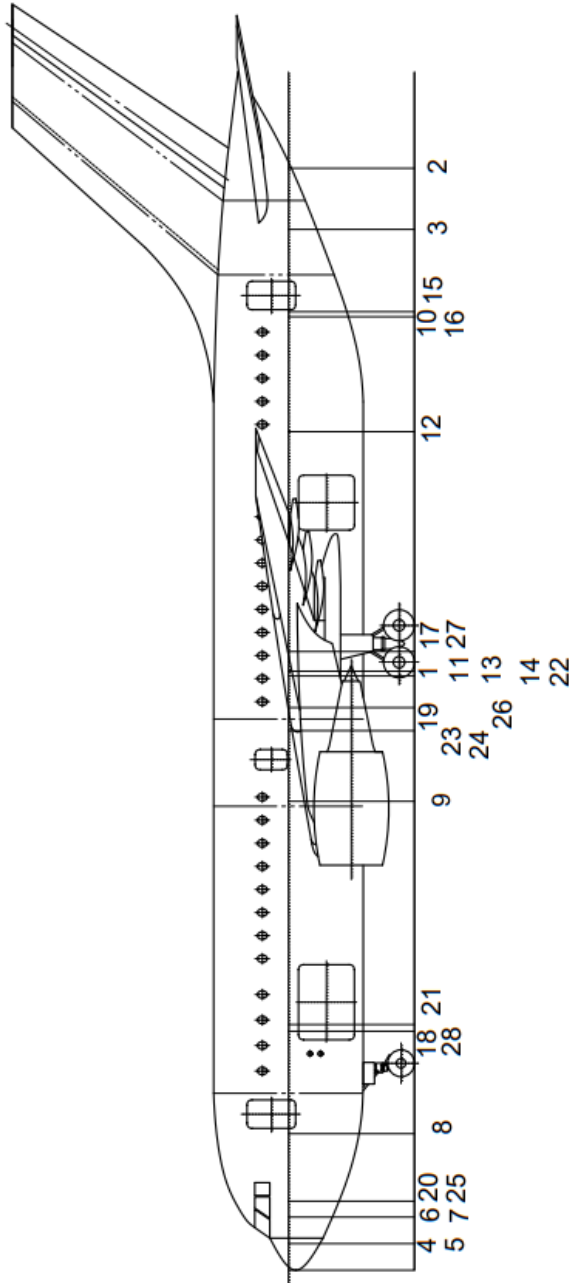
N	Name	C.G. coordinates x_i (m)
1	Wing (structure)	2,677626
2	Fuel system, 40%	2,7095025
3	Control system, 30%	3,82518
4	Electrical equip. 10%	0,63753
5	Anti-icing system 70%	0,63753
6	Hydraulic system, 70%	3,82518
7	Power units	-3,13
8	Equipped wing without fuel and LG	0,125810209
9	Nose landing gear	-12,293585
10	Main landing gear	3,506415
11	Fuel	2,868885



					NAU 24 08S 00 00 00 90			
					Center of gravity of the wing			
					Letter		Weight	Scale
								1:200
					Sheet 1		Sheets 2	
					Appendix B			
					404 ASF 134			
Ch.	Sheet	Document №	Sign.	Date				
Performed		Sydorenko K.O.						
Checked		Maslak T.P.						
Reviewed		Krasnopol'skiy V.S.						
Approved		Yutskevich S.S.						

Appendix C

N	Objects	Coordinates of C.G.
1	fuselage	22,56
2	horizontal tail	41,5
3	vertical tail	39,2
4	radar	1
5	radio equipment	1
6	instrument panel	2
7	aero navigation equipment	2
8	lavatory 1, lavatory 2, galley 1	5,14
9	lavatory 3, lavatory 4	17,66
10	lavatory 5, lavatory 6, galley 2	35,91
11	Flight control system 70%	22,56
12	hydraulic system 30%	31,584
13	electrical equipment 90%	22,56
14	lining and insulation	22,56
15	Anti-ice system, 20%	36,096
16	on board meal	35,91
17	passenger seats (economic class)	23,3
18	passenger seats (business)	9
19	seats of flight attendance	21,19
20	seats of pilot	2,6
21	Emergency equipment	8,1
22	Equipped fuselage without payload	22,382
23	baggage	19,02
24	cargo, mail	19,02
25	crew	2,6
26	flight attend	21,19
27	Passengers(economy)	23,3
28	Passengers(business)	9



NAU 24 08S 00 00 00 90

Ch.	Sheet	Document №	Sign.	Date
Performed		Sydorenko K.O.		
Checked		Maslak T.P.		
Reviewd		Krasnopol'skiy V.S.		
Approved		Yutskevich S.S.		

Center of gravity of
the fuselage






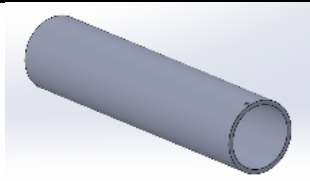

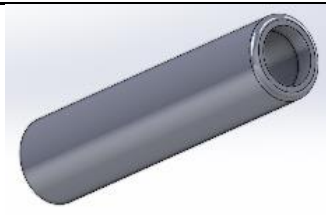

Letter	Weight	Scale
		1:200
Sheet 2	Sheets 2	


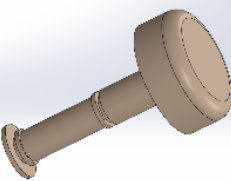
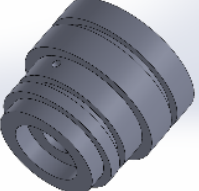
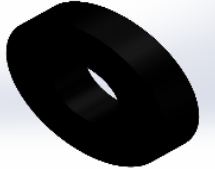
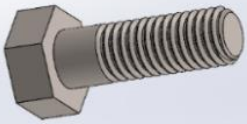
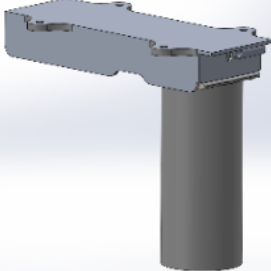

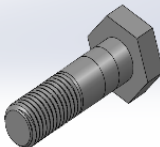
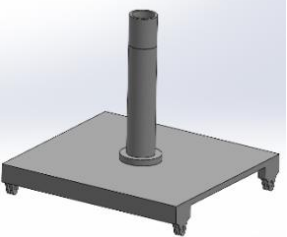
Appendix C

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Appendix D

Gas lift components

№	Name	Picture	Material
1	Gas lift clip		Copper
2	Washer M12		Steel
3	Sealing ring 2X24 (x2)		Rubber
4	Sealing ring 2X29		Rubber
5	Sealing ring 1X6		Rubber
6	Cylinder		Aluminum
7	Seal (x2)		Rubber
8	Hydraulic cylinder		Steel
9	Hydraulic cylinder holder		Steel

10	Piston rod		Steel
11	Adjustment button		Aluminum
12	Internal holder		Steel
13	Rubber gasket		Rubber
14	Bolt M8 (x4)		Steel
15	Piastra		Aluminum
16	Level arm		Aluminum
17	Bolt M10 (x4)		Steel
18	Floor fixing		Aluminum