**МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ**
**Національний авіаційний університет**
Кафедра конструкції літальних апаратів

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри, к.т.н., доцент
_________ Святослав ЮЦКЕВИЧ
«___» ____________ 2024 р.

**КВАЛІФІКАЦІЙНА РОБОТА**
ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ
**«БАКАЛАВР»**

**Тема: «Куленепробивні двері для пілотів»**

**Виконав:** __________ **Антон ПРИХОДЬКО**

**Керівник: к.т.н., доц.** __________ **Тетяна МАСЛАК**

**Нормоконтролер: к.т.н., доц.** __________ **Володимир КРАСНОПОЛЬСЬКИЙ**

Київ 2024

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

**PERMISSION TO DEFEND**
Head of the department,
Associate Professor, PhD.
______ Sviatoslav YUTSKEVYCH
"___"  ____________  2024

# BACHELOR DEGREE THESIS

## Topic: "Bullet-proof Door for the Cockpit"

| | | |
|---|---|---|
| **Fulfilled by:** | ____________ | **Anton PRYKHODKO** |
| **Supervisor:**<br>**PhD, associate professor** | ____________ | **Tetiana MASLAK** |
| **Standards inspector:**<br>**PhD, associate professor** | ____________ | **Volodymyr KRASNOPOLSKYI** |

Kyiv 2024

**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, к.т.н., доцент.
_________ Святослав ЮЦКЕВИЧ
«___» ____________ 2024 р.

**ЗАВДАННЯ**

**на виконання кваліфікаційної роботи здобувача вищої освіти**

ПРИХОДЬКО АНТОН ЄВГЕНІЙОВИЧ

1. Тема роботи: «Куленепробивні двері для пілотів», затверджена наказом ректора від 15 травня 2024 року № 794/ст.
2. Термін виконання роботи: з 20 травня 2024 р. по 16 червня 2023 р.
3. Вихідні дані до роботи: кількість пасажирів 174, дальність польоту з максимальним комерційним навантаженням 4500 км, крейсерська швидкість польоту 834 км/год, висота польоту 10,7 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 присвячено проектуванню конструкції вхідних дверей кабіни пілотів.
5. Перелік обов’язкового графічного (ілюстративного) материалу: загальний вигляд літака (А1×1), компонувальне креслення фюзеляжу (А1×1), 3D модель вхідних дверей пілотів.

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 проектованого літака. | 22.05.2024 – 23.05.2024 | |
| 3 | Виконання компонування літака та розрахунок його центрування. | 24.05.2024 – 25.05.2024 | |
| 4 | Розробка креслень по основній частині дипломної роботи. | 26.05.2024 – 27.05.2024 | |
| 5 | Аналіз джерел щодо вимог до вхідних дверей кабіни пілотів. | 28.05.2024 – 29.05.2024 | |
| 6 | 3D моделювання конструкції куленепробивних дверей. | 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 доповіді. | 08.06.2024 – 10.06.2024 | |
| 11 | Захист дипломної роботи. | 11.06.2024 – 16.06.2024 | |

7. Дата видачі завдання: 20 травня 2024 року

Керівник кваліфікаційної роботи ____________ Тетяна МАСЛАК

Завдання прийняв до виконання ____________ Антон ПРИХОДЬКО

**NATIONAL AVIATION UNIVERSITY**

Aerospace Faculty
Department of Aircraft Design
Educational Degree "Bachelor"
Specialty 134 "Aviation and Aerospace Technologies"
Educational Professional Program "Aircraft Equipment"

**APPROVED BY**
Head of Department,
Associate Professor, PhD.
______Sviatoslav YUTSKEVYCH
"____" ___________ 2024

**TASK**

for the bachelor degree thesis

**ANTON PRYKHODKO**

1. Topic: "Bullet-proof Door for the Cockpit", approved by the Rector's order № 794/ст from 15 May 2024.
2. Period of work: since 20 May 2024 till 16 June 2024.
3. Initial data: passenger capacity 174, flight range with maximum capacity 4500 km, cruise speed 834 km/h, flight altitude 10,7 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 about design of the flight deck door.
5. Required material: general view of the airplane (A1×1), layout of the airplane (A1×1), 3D model of flight deck door.

6. Thesis schedule:

| № | Task | Time limits | Done |
|---|---|---|---|
| 1 | Selection of initial data, analysis of flight technical characteristics of prototypes aircrafts | 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 | Analysis of the requirements to the flight deck door | 28.05.2024 – 29.05.2024 | |
| 6 | 3D model of the bullet-proof cockpit door | 30.05.2024 – 31.05.2024 | |
| 7 | Explanatory note checking, editing, preparation of the diploma work 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 work | 11.06.2024 – 16.06.2024 | |

7. Date of the task issue: 20 May 2024

Supervisor: ____________ Tetiana MASLAK

Student: ____________ Anton PRYKHODKO

# РЕФЕРАТ

Пояснювальна записка кваліфікаційної роботи бакалавра «Куленепробивні двері для пілотів»:

Дипломна робота присвячена ескізному проекту літака для авіаліній середнього класу з можливістю перевезення 174 пасажирів. У дипломній роботі представлена схема пасажирського салону з розміщенням пасажирського обладнання та облаштування. Особлива увага приділяється вимогам безпеки на борту.

Двері екіпажу беруться як предмет дослідження для дипломної роботи. Показано концептуальний проект дверної конструкції, використано композитні матеріали як матеріал конструкції, представлено петлі дверного кріплення. Особливу увагу приділено знімній панелі для евакуації з кабіни в разі блокування замка. Розрахунок напруженості дверної конструкції виконано під дією високошвидкісного удару на неї.

Для ескізного проектування літака беруться статистичні дані з прототипів для вибору найкращих конструктивних параметрів для проектування літака. AutoCad, SolidWorks, Abaqus CAE беруться для проектування літака, та моделювання дверей екіпажу.

Практична цінність дипломної роботи полягає у підвищенні безпеки на борту шляхом впровадження броне захисних дверей для кабіни.

Матеріали, представлені в дипломній роботі, можуть бути використані для авіаційної промисловості та для студентів, які вивчають пасажирське обладнання повітряних суден.

**Дипломна робота, аванпроект літака, компонування, центрування, двері кабіни пілотів, аналіз куленепробивної панелі**

# ABSTRACT

Bachelor degree thesis "Bullet-proof Door for the Cockpit"

This thesis is devoted to the preliminary design of a plane for mid-range airlines with the possibility to transport 174 passengers. The thesis presents the passenger cabin layout with an accommodation of passenger equipment and furnishings. The special attention is on the requirements for the safety on board.

The flight deck door is taking like the subject of the investigation for the thesis. The conceptual design of the door structure is shown, the composite materials are taking as a structure material, the hinges of the door attachment is presented. The special attention is devoted to the removable panel for the evacuation from the cockpit in case of blocking the lock. The stress-strain analysis of the door structure is performed under the action of the high velocity impact on it.

For the preliminary design of the aircraft the statistic data are taking from the prototypes to choose the best design parameters for designing aircraft. AutoCad, SolidWorks, Abaqus CAE are taking for the designing the aircraft, for the modeling of the flight deck door.

The practical value of the thesis is to improve safety on board by the implementation of bullet-prove door for the cockpit.

The materials presented in the thesis can be used for the aviation industry and for the students who learns the passenger equipment of aircraft.



**Bachelor thesis, preliminary design, cabin layout, center of gravity calculation, flight deck door, analyze of bullet-proof door**

| Format | № | Designation | Name | Quantity | Notes |
|---|---|---|---|---|---|
| | | | <u>General documents</u> | | |
| | | | | | |
| A4 | 1 | NAU 24 07P 00 00 00 80 TW | Task for work | 1 | |
| | | | | | |
| | | | | | |
| | 2 | NAU 24 07P 00 00 00 80 | Mid-range passenger aircraft | 2 | |
| | | | | | |
| A1 | | Sheet 1 | General view | 1 | |
| A1 | | Sheet 2 | Fuselage layout | 2 | |
| | | | | | |
| A4 | 3 | NAU 24 07P 00 00 00 80 EN | Bullet-proof Door for the Cockpit | 60 | |
| | | | Explanatory note | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | NAU 24 07P 00 00 00 80 EN | | | |
| | Sh. | № doc. | Sign | Date | | | | |
| Done by | | Prukhodko A.E. | | | Bullet-proof Door for the Cockpit (List of diploma work) | list | sheet | sheets |
| Supervisor | | Maslak T.P. | | | | Q | 9 | 60 |
| | | | | | | 404 ASF 134 | | |
| St.control. | | Krasnopolskyi V.S. | | | | | | |
| Head of dep. | | Yutskevich S.S. | | | | | | |

# CONTENT

# INTRODUCTION

Aviation has developed from simple creation of inventors to rapid engineering of modern planes, what demonstrating lines of a positive revolution in both civil and military domains. A wide variety of aircraft designs has been developed over the past hundred years to meet various needs. Still, there is one unifying factor that runs through these “Iron Birds”, the relentless search for the best.

Aviation safety nowadays is the one of the ICAO strategy. It is mean the safety of passengers in the airport terminals, safety of passengers on board. Except safety of passengers it is also mean the safety for cabin crew. So, the protection of pilots from intrusion in the cabin require the bullet-proof door.

The presented thesis is devoted to the preliminary design of the passenger aircraft with the attention to the safety requirement for the flight deck door. The conceptual design of the door is performed with the stress-strain analyses of the design. The ultra–high molecular weight polyethylene with epoxide resin composite materials is chosen for the bullet proof door panel structure.

# 1. PRELIMINARY DESIGN OF MID-RANGE AIRCRAFT

## 1.1. General data and prototypes

Preliminary design of the passenger aircraft is based on the statistical data of prototypes. The main prototypes for designing prototypes are Comac 919, B737-800, A 320, the main performances are shown in the table 1.1.

Selecting the optimal parameters for a new aircraft design are based on two critical factors: evaluating the efficiency of airplane on the intended purpose and the operational environment. Economic efficiency is paramount for the success of this aircraft. Complexity can improve performance but, at the same time, its introduction might lead to increased costs of development and production. The goal will be to seek the best algorithm with constant connection to feasibility and most importantly cost. Material selection is one of the most competent strategic steps that have to be taken with due consideration. Instead, we will take more emphasis in using cost-optimized materials that shall provide the adequate strength, durability and weight necessary for the structure.

*Table 1.1*

**Performances of prototypes**

| Parameter | Comac 919 | B737-800 | A 320 |
|---|---|---|---|
| 1 | 2 | 3 | 4 |
| Max. payload, kg | 20500 | 20540 | 16600 |
| Crew, number | 2/5 | 2/6 | 2/5 |
| Passengers sets | 156 | 168 | 150 |
| Flight range with max. payload, km | 4075 | 5460 | 5000 |
| Cruise speed, km/h | 960 | 828 | 828 |
| Cruise altitudes, km | 10.7 | 12.5 | 11.27 |
| Thrust/weight ratio, N/kg | 3.27 | 2.79 | 2.91 |
| Approach speed, km/h | 155 | 130 | 132 |
| Number and type of engines | 2 CFM56-5B | 2 CFM56-7B | 2 LEAP-1C |

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| Landing speed, km/h | 268 | 270 | 240 |
| Take-off speed, km/h | 268 | 270 | 240 |
| Take-off distance, m | 2600 | 2550 | 2090 |
| Landing distance, m | 1700 | 1636 | 1243 |
| Maximum take-off mass, kg | 72500 | 79010 | 68000 |
| Landing mass, kg | 68200 | 66361 | 64500 |
| Fineness ratio | 9,82 | 10,5 | 9,5 |
| Wing aspect ratio | 9.4 | 9.45 | 9.37 |
| Wing taper ratio | 4.1 | 4.5 | 4.11 |
| Fuselage length, m | 40.3 | 33.2 | 37.57 |
| Fuselage diameter, m | 3.95 | 3.76 | 3.95 |
| Fuselage fineness ratio | 10.91 | 10.21 | 9.51 |
| Passenger cabin width, m | 3.6 | 3.54 | 3.63 |
| Passenger cabin length, m | 34.9 | 29.95 | 27.5 |

## 1.2. Description of main parts

The plane employs a traditional aerodynamic low-wing design, accommodating six seats in one row. The fuselage has the circular shape, the wing has supercritical airfoil sweptback low wing and a standard tail configuration. The aircraft is equipped with two high bypass ratio engines positioned beneath the left and right wings, along with retractable tricycle landing gear.

### 1.2.1. Wing

The wings of the prototype feature a high aspect ratio with blended winglets at the tips for enhanced aerodynamic efficiency. They incorporate advanced aerodynamics, use composite materials for strength and lightness, and have a swept-back configuration for reduced drag and optimal performance. Also wing have supercritical design what increase aerodynamic efficiency by 20% and reducing drag by 8% compared to a non-supercritical wing. Center Wing Box is made like aluminum design (Before use carbon fiber composite)

Flaps are hinged sections on the trailing edge of the wings. During takeoff and landing, flaps extend downwards to increase lift at lower speeds. They retract during cruising flight to minimize drag. Ailerons are control surfaces also located on the trailing edge of the wings, but typically outboard of the flaps. They move in opposite directions to allow for roll control, enabling the aircraft to bank and turn. Slats are located on the leading edge of the wings and extend outwards during takeoff and landing. They increase the wing's camber (curvature) for improved lift at lower speeds. Spoilers are panels located on the upper surface of the wing. They can be deployed to disrupt airflow and increase drag, used for speed reduction during descent or to assist with braking after landing.

### 1.2.2. Fuselage

The prototype requires careful design and construction of its fuselage which is done with high grade materials and manufacturing technologies with emphasis placed on strength, durability and low weight. In terms of construction, it is mainly composed of light alloy metal, including aluminum alloy materials, and is characterized by high strength and low weight.

For the improvement of strength and stiffness of the fuselage there are several other strengthening members like bulkheads and floor beams. Bulkheads are referred to as dividers installed in the aircraft to divide specific regions, while the floor beams are girders which support the aircraft's floor and the cargo sections. The passenger cabin is separated from other compartments by a bulkhead. Within the nose and tail sections, there are entrance halls, a sideboard with a seat for a flight attendant, lavatories, and galleys.

### 1.2.3. Tail Unit

On the tail, both vertical and horizontal tail units show a greater sweep than the wing. This design makes certain that as the manipulations relevant to the Mach number increase, the aerodynamic characteristics of the tail unit are not diminished more dramatically as compared to the wing.

The cross section of the vertical tail is less thin or thin than the cross section of the horizontal tail, and has a relatively thicker airfoil profile. This design choice is made to reduce the amount of the load applied on fin member due to force exerted by both the vertical and the horizontal part.

It has been observed that the arrangement of the empennage of the aircraft has some features where the assembled panels are attached to the Spars Web. This method also increases the clearance as well as ease of assembly when the device is being manufactured. The aircraft has a resilient control column, allowing control of flight across a variety of speeds, without losing stability and overall centering anywhere on the range.

### 1.2.4. Landing gear

The two wheels are provided by two Main Landing Gear units, and each unit includes an oleo-pneumatic shock strut. As for Brakes these wheels are installed with carbon ones. Regarding the particular one of the nose landing gear, the part and characteristic of it are as follow: the type of the front portion is two wheels, oleo-pneumatic shock strut, and nose wheel steering system.

In this position, the lock stay is arranged in a straight manner; however, it is secured in a position that is 5° over center by the force of the down lock springs hence it shall be steady against shifts. This position ensures that the landing gear remains in the down and locked position to provide a stable surface for the plane's weight. In order to retract the landing gear, down lock release actuator should overcome the force exerted by down lock spring which thus makes it possible for the lock stay shift from over center and locked to perform gear retraction.

### 1.2.5. Avionics system

The aircraft's avionics system is developed by GE and the AVIC System. The avionics include core processing, display, and on-board maintenance systems. The aircraft has a modular avionics system, such as a central information system that performs avionics, maintenance, and utility functions.

Beyond the overall aircraft structure, the prototype must provide insights into what we can expect for the cockpit. Modern trends suggest a digital glass cockpit layout with advanced avionics for flight control, navigation, and communication, likely incorporating Head-Up Displays (HUDs) for improved situational awareness. Pilot and co-pilot stations will be ergonomically designed for comfort and reduced fatigue during long flights. The level of automation remains to be seen, but cybersecurity will undoubtedly be a top priority to safeguard critical flight control systems. In conclusion, the like COMAC C919 offers valuable benchmarks for our proposed short and medium-haul passenger aircraft, while the broader industry trends in cockpit design point towards a technologically advanced and pilot-friendly environment that prioritizes safety and efficiency.

### 1.2.6. Power plant

In 2009, Pratt & Whitney and CFM International presented engine options for the aircraft: it is the PW1000G for aircraft and the LEAP-1C for engines. LEAP-1C engine was eventually selected as the best one for the sale. Similar variant is engine produced by the same company is also used in Airbus A320 neo and Boeing 737 MAX aircraft types.

Lifting capacity of LEAP-1C engine is 31,000 lbf of maximum takeoff trust. The subheading related to fans is Fan Diameter which measures 77 inches. To integrate and optimize the overall aerodynamic efficiency, the engine is integrated with a fully integrated propulsion system (IPS), which comprises of the engine, nacelle and the thrust reverser.

This engine model is a high-bypass turbofan engine with a two-shaft design for the LEAP-1C. It comes with an engineering plastic 3D woven composite material and the RTM or the resin transfer molding process that has been owned and designed by Safran Aircraft Engines to enable the creation of next generation fan bladed that has very superior features such as being light, strong and also very durable. The low pressure turbine blades are cut from an exclusive titanium-aluminide alloy, which is lighter and more core tolerant than the materials used conventionally.

**Conclusions to the analytical part**

The presented part of the qualification work is devoted to the substantiation of the performances for the designing aircraft. The short description of the aircraft parts are described. After analyzing of the presented prototypes and their data, the most suitable for our requirements in terms of engine, number of passengers, maximum payload is suitable Comac C919. So, this aircraft design is taken like the base for designing aircraft.

## 2. PRELIMINARY DESIGN OF AIRCRAFT

### 2.1. Geometry calculations of the main parts of the aircraft

The aircraft layout involves arranging its components, considering various loads and ensuring they meet operational needs. Calculating the aircraft layout involves determining the design's purpose, dimensions, and operational needs. It includes geometry calculations for major structural parts.

#### 2.1.1. Wing geometry calculation

According to the initial data, the aspect ratio of the wing is taken 8.78, the taper ratio of the wing is 4.00, sweep back angle of a wing is 27°.

Wing area is calculated by the formula:

$$S_w = \frac{m_0 \cdot g}{P_0} = \frac{79822 \cdot 9.81}{6567} = 150\ \text{m}^2,$$

where $m_0$ – take-off weight, kg; $g$ – gravity acceleration, m/s$^2$; $P_0$ – specific wing load,

Wing span is:

$$l_w = \sqrt{S_w \cdot \lambda_w} = \sqrt{150 \cdot 8.78} = 36.3\ \text{m},$$

where $\lambda_w$ – wing aspect ratio.

Root chord is:

$$C_{root} = \frac{2S_w \cdot \eta_w}{(1+\eta_w) \cdot l_w} = \frac{2 \cdot 150 \cdot 4}{(1+4) \cdot 36.3} = 6.61\ \text{m},$$

where $\eta_w$ – wing taper ratio.

Tip chord is:

$$C_{tip} = \frac{C_{root}}{\eta_w} = \frac{6.61}{4} = 1.65\ \text{m}.$$

In order to determine the concept of mean aerodynamic chord the geometrical method was applied (fig. 2.1). According to the geometrical method, this is obtained by taking a straight line parallel to the chords line which can be drawn at the intersection of the section joining two middle points of the tip and root chords with another section which may join the upper end extension of tip chord which is equal to the length of root chord as well as the lower extension of the root chord. This method was preferred because of efficiency and ease of carrying out the seen procedures.

The mean aerodynamic chord is equal to $b_{MAC}$ = 3,64 m.

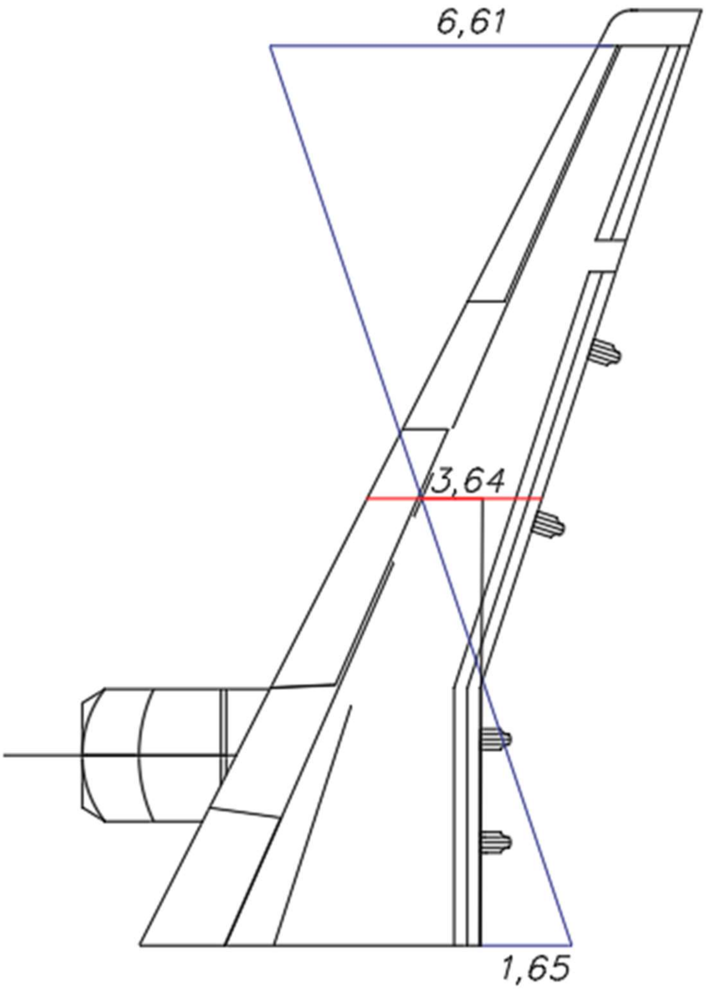



Fig. 2.1. Geometrical method of determination of mean aerodynamic chord.

Ailerons span:

$$l_{ail} = 0.3 \cdot \frac{l_w}{2} = 0.3 \cdot \frac{36.3}{2} = 5.4 \text{ m}.$$

Aileron chord:

$$b_{ail} = 0.2 \cdot C_{tip} = 0.2 \cdot 1.65 = 0.33\,\text{m}.$$

Aileron area:

$$S_{ail} = 0.05 \cdot \frac{S_w}{2} = 0.05 \cdot \frac{150}{2} = 3.75\,\text{m}^2.$$

Range of aileron deflection for upward is 25 degrees. For high lift device is 1.05, so take Double slotted Faylers flaps together with slats.

### 2.1.2. Fuselage layout

Generally, the fuselage layout estimation consists of main geometrical dimensions calculation and interior scheme creation.

Fuselage layout consists of a comfortable accommodation of passengers in the cabin. The fuselage structure is composed of bulkheads (formers and frames), stringers (longerons), and skin. Formers determine the fuselage shape and provide support for the stringers and skin. These formers are installed in parallel and linked with stringers. Frames bear the primary loads, including concentrated forces from the wing, tail, landing gear attachment, near entrance and emergency exits, and cargo doors (fig. 2.2).

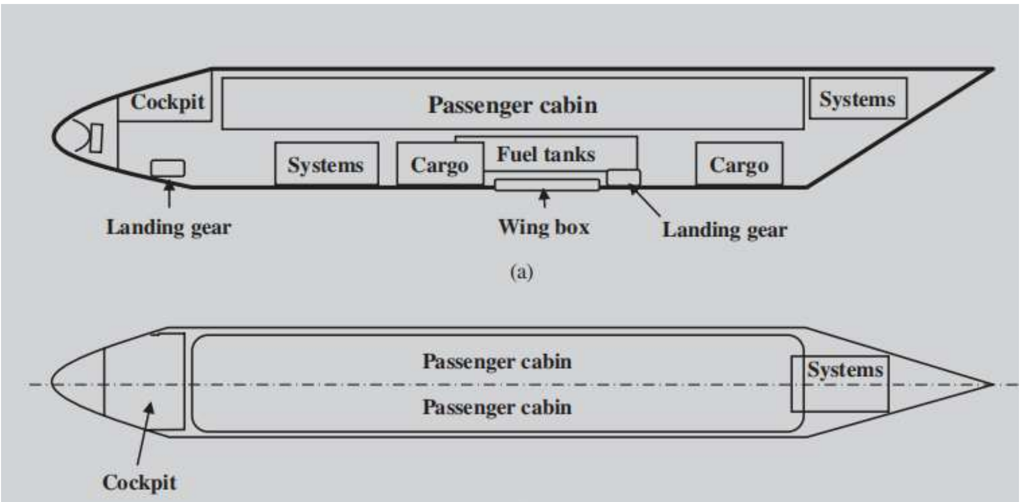



Fig. 2.1. Preliminary design of aircraft layout.

Fuselage length is:

$$l_{fus} = FR_f \cdot D_{fus} = 9.82 \cdot 3.96 = 38.88\,\text{m},$$

where $FR_f$– fuselage fineness ratio.

Forward part length:

$$l_{fwd} = 1.2 \cdot D_{fus} = 1.2 \cdot 3.96 = 4.75\,\text{m},$$

Fuselage Forward part fineness ratio:

$$FR_{fwd} = \frac{l_{fwd}}{D_f} = \frac{4.75}{3.96} = 1.2,$$

Length of the fuselage Tail part:

$$l_{tailpart} = FR_{tu} \cdot D_f = 1.5 \cdot 3.76 = 5.94\,\text{m},$$

where $FR_{tu}$– fuselage rear part fineness ratio.

For 174 passengers and short range of flight take mono-class like economic with 3+3 in one row (When we have 29 rows):

$$B_{cab} = n_{3chblock} \cdot b_{3chblock} + b_{aisle} + 2 \cdot \delta + 2 \cdot \varphi =$$
$$= 2 \cdot 1560 + 520 + 2 \cdot 40 + 2 \cdot 120 = 3960\,\text{mm},$$

where $n_{3chblock}$ – width of 3 chairs; $b_{3hblock}$ – number of 3 chair block; $b_{aisle}$ – width of aisle; $\varphi$ – wall.

Cabin height:

$$H_{cab} = 1.48 + 0.17 B_{cab} = 1.48 + 0.17 \cdot 3.96 = 2.1532\,\text{m},$$

where $B_{cab}$ – width of the cabin.

The length of passenger cabin:

$$L_{cab} = L_1 + (n_{raws} - 1) \cdot L_{seatpitch} + L_2 = 1200 + (29 - 1) \cdot 750 + 230 = 22430\ \text{mm},$$

where $L_1$ – distance between the wall and the back of first seat; $n_{rows}$ – number of rows; $L_{seatpitch}$ – seat pitch; $L_1$ – distance between the back of last seat and the wall.

### 2.1.3. Baggage compartment

Unit load on floor $K$ = 400…600 kg/m$^2$.

The area of cargo compartment:

$$S_{cargo} = \frac{M_{bag}}{0.4 \cdot K} + \frac{M_{c\&m}}{0.6 \cdot K} = \frac{174 \cdot 20}{0.4 \cdot 500} + \frac{174 \cdot 15}{0.6 \cdot 500} = 26.1\ \text{m}^2,$$

where $M_{bag}$ – mass of the baggage, kg; $M_{c\&m}$ – mass of the cargo and mail, kg.

Cargo compartment volume is:

$$V_{cargo} = \nu \cdot n_{pass} = 0.22 \cdot 174 = 38.28\ \text{m}^3,$$

where ν – relative mass of baggage (0.22 for $D_f \le 4$ m and 0.38 for $D_f > 4$ m); $n_{pass}$ – number of passengers.

Baggage compartment design is similar to the prototype.

### 2.1.4. Galleys and buffets

Volume of buffets (galleys) is:

$$V_{galley} = (0.1...0.12) \cdot n_{pass} = 0.1 \cdot 52 = 17.4\ \text{m}^3,$$

where $V$ – volume of buffets; $n_{pass}$ – number of passengers.

Area of buffets (galleys) floor is:

$$S_{galley} = \frac{V_{galley}}{H_{cab}} = \frac{17.4}{2.15} = 8.09\ \text{m}^2,$$

Number of meals per passenger breakfast, lunch and dinner – 0.8 kg per passenger; tea and water – 0.4 kg per passenger, the total weight of food for passenger and crew number is about 210 kg. Buffet design is similar to the prototype.

### 2.1.5. Lavatory design

Number of toilet facilities is determined by the number of passengers and flight duration: with t > 4 hours should be one toilet for 40 passengers. The number of lavatories is equal to:

$$t = \frac{Range_{flight}}{V_{cruise}} + 0.5 = \frac{5200}{828} + 0.5 = 6.78\,\text{h},$$

$$N_{lav} = \frac{n_{pass}}{40} = \frac{174}{40} = 4.3,$$

So, the chosen number of lavatories is 4. Area of each lavatory is 1.6 m$^2$ and width of module – 1 m. Lavatories design is similar to the prototype.

### 2.1.6. Tail unit

Provides statistical data for the range of static moment coefficients ($A_{htu}$ for the horizontal tail unit and $A_{vtu}$ for the vertical tail unit) along with typical arm lengths relative to the mean aerodynamic chord of the wing. This information assists in the initial estimation of geometric parameters

To outline the overall dimensions of the tail unit accurately, it's essential to calculate the geometrical aspects of both the vertical and horizontal stabilizers, including the dimensions of control surfaces. Ultimately, the tail unit's design must fulfill the requirements for the aircraft's stability and controllability.

Area of vertical tail unit is:

$$S_{VTU} = \frac{b_{mac} \cdot S}{L_{VTU}} \cdot A_{VTU} = \frac{3.64 \cdot 150}{18.53} \cdot 0.065 = 19.15\ \text{m}^2,$$

where $L_{VTU}$ – length of vertical tail unit; $A_{VTU}$ – coefficient of static moment of vertical tail unit.

Area o horizontal tail unit is:

$$S_{HTU} = \frac{b_{mac} \cdot S}{L_{HTU}} \cdot A_{HTU} = \frac{36.3 \cdot 150}{18.39} \cdot 0.062 = 17.7\ \text{m}^2,$$

where $L_{HTU}$ – length of horizontal tail unit; $A_{HTU}$ – coefficient of static moment of horizontal tail unit.

Determination of the elevator area and direction:

Altitude elevator area is:

$$S_{el} = k_{el} \cdot S_{HTU} = 0.3 \cdot 19.15 = 5.745 \text{ m}^2,$$

where $k_{el}$ – relative elevator area coefficient ($k_{el}$ = 0.3…0.4).

Rudder area is:

$$S_{rud} = k_r \cdot S_{HTU} = 0.22 \cdot 17.7 = 3.894 \text{ m}^2,$$

where $k_r$ – relative rudder area coefficient, $k_r$ = 0.2…0.45.

Choice of the axial balance for elevator and rudder for the subsonic flight should be taken by the formular:

$$S_{eb} = (0.22...0.25) \cdot S_{el} = 0.22 \cdot 5.745 = 1.2639 \text{ m}^2,$$

$$S_{rb} = (0.2...0.22) \cdot S_{rud} = 0.2 \cdot 3.89 = 0.778 \text{ m}^2,$$

where $k_{eb}$ – relative elevator balance area coefficient; $k_{rb}$ – relative rudder balance area coefficient.

The area of elevator trim tab is:

$$S_{te} = k_{te} \cdot S_{el} = 0.08 \cdot 5.745 = 0.4596 \text{ m}^2,$$

where $k_{te}$ – relative elevator trim tab area coefficient ($k_{te}$ = 0.08…0.12).

Area of rudder trim tab is:

$$S_{tr} = k_{tr} \cdot S_{rud} = 0.8 \cdot 3.89 = 3.112 \text{ m}^2,$$

where $k_{tr}$ – relative trim tab area coefficient.

Taper ratio for the horizontal tail is $\eta_{HTU}$ =2 and for the vertical tail unit is $\eta_{VTU}$=1,3.

The root chord of horizontal stabilizer is:

$$b_{tipHTU} = \frac{2 \cdot S_{HTU}}{(\eta_{HTU} + 1) \cdot L_{HTU}} = \frac{2 \cdot 19.15}{(2+1) \cdot 11.61} = 1.09 \text{ m},$$

where $\eta_{HTU}$ – horizontal tail unit taper ratio; $L_{HTU}$ – horizontal tail unit span.

Tip chord of horizontal stabilizer is:

$$b_{tHTU} = b_{tipHTU} \cdot \eta_{HTU} = 1.09 \cdot 2 = 2.18 \text{ m},$$

Root chord of vertical stabilizer is:

$$b_{tipVTU} = \frac{2 \cdot S_{VTU}}{(\eta_{VTU} + 1) \cdot L_{VTU}} = \frac{2 \cdot 3.55}{(1{,}3 + 1) \cdot 6.534} = 2.35 \text{ m},$$

where $\eta_{VTU}$ – vertical tail unit taper ratio; $L_{VTU}$ – vertical tail unit span.

Tip chord of vertical stabilizer is:

$$b_{tVTU} = b_{tipVTU} \cdot \eta_{VTU} = 2.35 \cdot 1.3 = 3.055 \text{ m},$$

Mean aerodynamic chord for VTU/HTU:

$$b_{HTUmac} = 0.66 \frac{\eta^2{}_{HTU} + \eta_{HTU} + 1}{(\eta_{HTU} + 1)} \cdot b_{HTUtip} = 0.66 \frac{2^2 + 2 + 1}{2 + 1} \cdot 1.09 = 1.67 \text{ m},$$

$$b_{VTUmac} = 0.66 \frac{\eta^2{}_{VTU} + \eta_{VTU} + 1}{(\eta_{VTU} + 1)} \cdot b_{VTUtip} = 0.66 \frac{1.3^2 + 1.3 + 1}{1.3 + 1} \cdot 2.35 = 2.69 \text{ m},$$

The value of the mean aerodynamic chord for VTU/HTU are necessary for the definition of the arm of tail unit and for the balance of the aircraft.

### 2.1.7. Landing gear

To determine the landing gear outline in this project, it is necessary to calculate the relative location of each strut, estimate the loads on the landing gear system, and consider the center of gravity of the airplane. The principal scheme of the landing gear in this layout is based entirely on prototype data.

Distance from the center of gravity to the main LG:

$$Bm = k_c \cdot b_{MAC} = 0.2 \cdot 3.64 = 0.728 \text{ m},$$

where $k_c$ – coefficient of center of gravity ($k_e$ = 0.15…0.20); $b_{MAC}$ – mean aerodynamic chord of a wing.

Landing gear wheel base is:

$$B = k_b \cdot L_{fus} = (6...10) \cdot \mathrm{B_m} = 10 \cdot 0.728 = 7.28,$$

where $k_b$ – wheel base calculation coefficient ($k_b$ = 0.3…0.4).

Nose support carries 6-10% of airplane weight. Distance from thee center of gravity to the nose LG:

$$B_n = B - B_m = 7.28 - 0.728,$$

Wheel track is:

$$T = k_T \cdot B = 1.2 \cdot 7.28 = 8.736 \text{ m} < 12\text{m}$$

where $k_T$ – wheel track calculation coefficient ($k_T$ = 0.7…1.2).

Nose wheel load is:

$$F_{nose} = \frac{B_m \cdot m_0 \cdot 9.81 \cdot K_g}{B \cdot z} = \frac{0.728 \cdot 79822 \cdot 9.81 \cdot 2}{7.28 \cdot 2} = 78305 \text{ N},$$

where $k_d$ – dynamics coefficient ($k_d$ = 1.5…2.0); $z$ – number of wheels.

Main wheel load is equal to:

$$F_{nose} = \frac{B_m \cdot m_0 9 \cdot ,81}{B \cdot z \cdot n} = \frac{6.552 \cdot 79822 \cdot 9.81}{7.28 \cdot 2 \cdot 2} = 176187.1 \text{ N},$$

where $n$ – number of main landing gear struts.

The next step is to go to the catalogue of Good year tires and choose the tires for the landing gear with our result of calculations:

For nose wheel:

$F_{rated}$ = 17800 lbf (79178.34 N), v = 210 MPH D 34×9.25-16 inch

For main wheel:

$F_{rated}$ = 41500 lbf (184601.2 N), v = 225 MPH D H46×18.0-20 inch

### 2.2. Determination of the aircraft center of gravity position

The centre of gravity range is the range of the centre of gravity of the aircraft in relative coordination from mean aerodynamic chord of a wing. The range of the centre of gravity helps to provide balance of the aircraft according to the change in the loading cases of the aircraft or weight shift. They also conclude that the shifting of the cargo from one part of the aircraft to the other also brings about the shifting of the position of the center of mass.

The centering is one of the crucial properties off the aircraft since it determines balancing, stability and controllability of the aircraft. This is why it is needed to maintain its levels within a very certain range, strict in most cases.

Another key aspect of an aircraft's configuration is its longitudinal static stability which is provided by placing the center of mass relative to the aerodynamic centre position of a wing. In simpler terms this mean that when the center of mass positioned nearer to the nose part of the aircraft more longitudinal stability the aircraft will possess.

#### 2.2.1. Determination of centering of the equipped wing

The first stage of trim sheet calculation is performed for the masses of a wing. The list of the mass objects of a wing, where the engines are located under the wing, is given in the table 2.1. Coordinates of the center of mass for the equipped wing are determined by the formula:

$$X'_w = \frac{\sum m'_i \cdot x_i}{\sum m'_i},$$

where $X'_w$ – center of mass for equipped wing, m; $m'_i$ – mass of a unit, kg; $x_i$ – center of mass of the unit, m.

**List of equipped wing masses**

| # | Object name | Mass | | Center of gravity coordinates, m | Moment of mass, kg·m |
|---|---|---|---|---|---|
| | | Units | Total mass, kg | | |
| 1 | Wing (structure) | 0.10554 | 8424.413 | 1.565 | 13185.892 |
| 2 | Fuel system | 0.0075 | 598.665 | 1.547 | 926.134 |
| 3 | Flight control system, 30% | 0.00192 | 153.258 | 2.184 | 334.715 |
| 4 | Electrical equipment, 20% | 0.00323 | 257.825 | 0.364 | 93.848 |
| 5 | Anti-icing system, 70% | 0.00658 | 525.228 | 0.364 | 191.183 |
| 6 | Hydraulic system, 30% | 0.01225 | 977.819 | 2.184 | 2135.557 |
| 7 | Power plant | 0.0871 | 6952.496 | -1.9 | -13209.742 |
| | Equipped wing without landing gear and fuel | 0.22412 | 17889.70 | 0.204 | 3657.5899 |
| 8 | Nose landing gear | 0.00602 | 480.528 | -13.1 | -6294.9225 |
| 9 | Main landing gear | 0.0341 | 2721.9302 | 1.2 | 3266.316 |
| 10 | Fuel for flight | 0.25663 | 20484.719 | 1.092 | 22369.314 |
| | Totally equipped wing | 0.52087 | 41576.884 | 0.5531511 | 22998.297 |

### 2.2.2. Determination of the centering of the equipped fuselage

Mass of the equipped fuselage includes mass of fuselage structure, mass of all systems equipment, commercial payload and passenger equipment, crew, attendants. In the trim sheet, we can input name of an object, its mass and the coordinates of its center of gravity from the nose of the fuselage. In fact, the list of objects including in the equipped fuselage trim sheet are shown in the table 2.2. The center of gravity coordination of the equipped fuselage is determined as the sum of mass moments divided to the masses by formula:

$$X'_f = \frac{\sum m'_i \cdot x_i}{\sum m'_i},$$

where $X'_f$ – center of mass for equipped fuselage, m; $m'_i$ – mass of a unit, kg; $x_i$ – center of mass of the unit, m.

*Table 2.2*

**Equipped fuselage masses**

| № | Object name | Mass | | Center of gravity coordinates, m | Moment of mass, kg·m |
|---|---|---|---|---|---|
| | | Units | Total mass, kg | | |
| 1 | Fuselage | 0.0882 | 7040.3004 | 19.44 | 136863.439 |
| 2 | Horizontal tail unit | 0.01104 | 881.23488 | 34.7 | 30578.850 |
| 3 | Vertical tail unit | 0.01089 | 869.26158 | 35 | 30424.155 |
| 4 | Radiolocation equipment | 0.0031 | 247.448 | 1 | 247.448 |
| 5 | Instrument panel equipment | 0.0055 | 439.021 | 2 | 878.042 |
| 6 | Aero navigation equipment | 0.0047 | 375.163 | 2 | 750.326 |
| 7 | Radio equipment | 0.0023 | 183.590 | 1 | 183.590 |
| 8 | Flight control system, 70% | 0.00448 | 357.602 | 21.38 | 7645.542 |
| 9 | Electrical equipment, 90% | 0.02907 | 2320.425 | 19.44 | 45109.072 |
| 10 | Hydraulic system, 30% | 0.00525 | 419.065 | 18.33 | 7681.470 |
| 11 | Anti-icing system, 20% | 0.00329 | 262.614 | 34.55 | 9073.326 |
| 12 | Air-conditioning system | 0.002820 | 225.098 | 17.5 | 3939.2157 |
| 13 | Emergency equipment | 0.0062 | 500 | 19.44 | 9720 |
| 14 | Additional equipment | 0.01364 | 4 | 4.126 | 3810.702 |
| 15 | Lining and insulation | 0.0078 | 1088.77208 | 3.55 | 10895.703 |
| 16 | Lavatory and galleys1 | 0.0100223 | 800 | 13 | 10400 |
| 17 | Lavatory and galleys 2 | 0.0100223 | 800 | 32 | 25600 |
| 18 | Operational items | 0.002126 | 169.70 | 19.44 | 3298.96 |
| 19 | Passengers' seats (economic | 0.01743 | 1392 | 19.44 | 27060.48 |
| 20 | Pilots' seats | 0.0003 | 30 | 2.5 | 75 |
| 21 | Flight attendants' seats | 0.0006 | 48 | 17.1 | 820.8 |
| 22 | Non-typical equipment | 0.0049 | 391.12 | 5 | 1955.639 |
| | Equipped fuselage without commercial load | 0.2438 | 19463,03 | 18.85 | 367011.80 |
| 23 | Passengers (economic class) | 0.1723 | 13756 | 19.44 | 267416.64 |
| 24 | Passengers' baggage | 0.04384 | 3500 | 19.44 | 68040 |
| 25 | Cargo, mail | 0.01227 | 980 | 9.8 | 9604 |
| 26 | On board meal | 0.003285 | 262,22 | 24.5 | 6424,39 |
| 27 | Flight attendants | 0.00451 | 360 | 17.1 | 6156 |
| 28 | Crew | 0.00192 | 154 | 2.5 | 385 |
| | Totally equipped fuselage | 0.4820 | 38475.25 | 18.8442 | 725037.8342 |

### 2.2.3. Calculation of center of gravity positioning variants

After the center of gravity of fully equipped wing and fuselage is determined, the moment equilibrium equation relatively to the fuselage nose can been made:

$$m_f \cdot X'_f + m_w(X_{MAC} + X'_w) = m_0(X_{MAC} + C),$$

where $m_0$ – aircraft take-off mass, kg; $m_f$ – mass of fully equipped fuselage, kg; $m_w$ – mass of fully equipped wing, kg; $C$ – distance from MAC leading edge to the center of gravity point determined by the designer.

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

$$X_{MAC} = \frac{m_f \cdot X'_f + m_w \cdot X'_w - m_0 \cdot C \cdot b_{MAC}}{m_0 - m_w},$$

$$X_{MAC} = \frac{38475 \cdot 18.844 + 41576.8 \cdot 0.553 - 79822 \cdot 0.24 \cdot 3.64}{79822 - 41576.8} = 18.22 \text{ m},$$

The list of mass objects for center of gravity variants calculation is given in table 2.3 and center of gravity calculation options are given in table 2.4 completed on the data from previously tables.

*Table 2.3*

**Calculation of center of gravity position variants**

| № | Object name | Mass, kg | Center of gravity coordinates, m | Moment of mass, kg·m |
|---|---|---|---|---|
| 1 | Equipped wing without landing gear and fuel | 17889.71 | 17.86 | 319584.84 |
| 2 | Nose landing gear (extended) | 480.53 | 5.503 | 2642.91 |
| 3 | Main landing gear (extended) | 2721.93 | 19.60 | 53349.83 |
| 4 | Fuel for flight | 17725.27 | 18.75 | 332379.40 |
| 5 | Reserve fuel | 2759.45 | 18.75 | 51744.38 |
| 6 | Equipped fuselage without commercial load | 19463.04 | 18.86 | 367011.80 |
| 7 | Passengers (economic class) | 13398 | 19.44 | 260457.12 |
| 8 | Baggage of passengers | 3500 | 19.44 | 68040.00 |
| 9 | Cargo, mail | 980 | 19.44 | 19051.20 |
| 10 | On board meal | 262.22 | 21.4 | 5611.51 |
| 11 | Flight attendants | 360 | 17.1 | 6156.00 |
| 12 | Crew | 154 | 2.5 | 385.00 |
| 13 | Nose landing gear (retracted) | 480.52844 | 3.94 | 1893.28 |
| 14 | Main landing gear (retracted) | 2721.9302 | 19.6 | 53349.83 |

*Table 2.4*

**Aircraft center of gravity position variants**

| № | Variant of loading | Mass, kg | Moment of mass, kg·m | Center of gravity coordinates, m | Centering, % |
|---|---|---|---|---|---|
| 1 | Take-off mass (LG extended) | 79694.14 | 1486413.99 | 18.65148321 | 27.24 |
| 2 | Take-off mass (LG retracted) | 79694.14 | 1485664.37 | 18.64207695 | 26.98 |
| 3 | Landing variant (LG extended) | 61968.87 | 1154034.59 | 18.62281129 | 26.45 |
| 4 | Transportation variant (without payload) | 61193.92 | 1126348.54 | 18.40621525 | 20.50 |
| 5 | Parking variant (without fuel and payload) | 43314.65 | 794333.76 | 18.3386855 | 18.652 |

**Conclusions to the project part**

In this part, the major geometric dimensions of the developed airplane were determined: the wing parameters are calculated, the fuselage design is presented with the accommodation of passengers in saloon, the tail unit is calculated according to the prototypes and mass balance of the aircraft, the loads on landing gear are calculated with the choice of tires from Goodyear catalog and the engine selection is done.

The second part of the preliminary design is about center of gravity calculation. The mass distribution of the main parts and systems were performed according to the requirements of aircraft balance and control. The center of gravity range is the most forward is 18% from the leading edge of mean aerodynamic chord in parking version and a maximum aft position in take-off mass with 27% from leading edge of mean aerodynamic chord. Between these values, the plane is centered.

On the basis of the presented parameters, the general view and layout of the aircraft are performed.

# 3. CONCEPTUAL DESIGN OF BULLET-PROOF DOOR FOR THE COCKPIT

## 3.1. State of the art - safety on board

Security is the one of the important things in the modern aviation. Security divided on the security of the Airport and security on the Plane. Strict rules, inspections, air marshals and, of course, the design of various elements in the aircraft help to maintain the safety of passengers, pilots and crew in various critical situations.

Safety on board is a wide requirement. At the presented paper we will focus on the safety of pilot by the designing of the bullet-proof door in a cabin. Armored doors are precisely the element that helps prevent the entry to the flight deck without access for not authorized persons and save the lives of pilots and passengers, and people who are not even on the plane in case of aircraft disaster. These barriers that have been subjected to various levels of intrusion and a bullet fired at them offer a mandatory security barrier against intrusion.

It is good to remember that the measures which are in practice today are quite different from what the world used to practice before September 11, 2001. Before the tragedy, the specifications of cockpit doors were not as strict. Its main purpose was more technical, they was designed to isolate pilots from passengers conversations and daily activities. Specifically, in the small planes, for instance, then more simple partitions could suffice for doors in their entirety. For the duration of this period, the appropriate action to be taken by the pilots, who come face to face with hijackers, was more submissive action for the safe of passengers and the aircraft.

Most cockpits doors had lock mechanisms that could be locked and had some form of enhanced structure. For example, older generation Boeing 737 aircraft had doors, which were more against explosion than bullets and could resist small arms fire too, like 9 mm bullets. But the incident with four airplanes and terrorists attack shock the world and caused a major change in aviation safety measures.

That time was to the change, with preventing hijacking at all costs becoming the ultimate goal. As a result, entry to cockpit was restricted and cockpit doors got fortified. In addition, some prescribed rules of FAA closely related with flight practice and some general guidelines contained in Advisory Circular (AC) 25 was updated. Regulation 795(1) and (2), have updated to necessitate the pilot's door, also known as the cockpit door, to be closed during the flying time [1,2].

However, there is no denying the fact that the penchant for more security has its challenges. A real life example of this can be seen in the Germanwings Flight 9525 crash in March 2015, where a pilot intentionally plunged the aircraft into the mountain. This situation gave rise to discussions and recommendations of various federations for the presence of two more people in addition to the pilots in the cockpit, but it's only recommendation what not as strict rules.

Therefore, from the above and history, it is possible to highlight the basis for cabin doors in the importance of design and safety when developing bulletproof doors for use on aircraft.

### 3.2 Requirements for the flight deck doors

The main purpose of this section is to understand the requirements for door design and protection, as well as the Federal Aviation Administration's safety regulations. Taking into account all regulation it will be possible to understand how to make a design of a door of our aircraft.

The main requirements for flight deck doors can be easy found in FAA Advisors Circular (25). The most interesting and important is 25.795(1) [1] about Intrusion Resistance and 25.795(2) [2]. Penetration Resistance of the door, also in this documents can be found tests criteria and how to provide them.

### 3.2.1. Requirements of intrusion resistance

This Advisory Circular relates to the capacity of force of resistance and people that are unauthorized to access the flight deck without pilots' consent and this includes the force entry accompanied by simple tools such as knives, keys, credit cards, among others.

Main Requirements presented in paragraph 25.795(1) [1] explain: if person who not authorized gains entry to the flight deck without access – safety of plane and passengers/crew is at risk; cockpit doors design and usage are restricted by certain requirements, for instance, §121. 313 and 121. 587. These regulations increase flight safety by prescribing such specifications as the possibility of installing a door between the pilot cockpit and the passenger area. Also they require that the pilot in command ensure that the door is closed and locked at the commencement of the flight and throughout the flight. Regulation 25.772 talks about situation when pilots are incapacitated or door can be opened, in situation when door jammed. Flight crew members must have access to flight deck from outside if this situation have happened.

The locking mechanisms were often vulnerable to force entry, such as kicking. Features like hinges and locks should resist easy overload, and door knobs should be designed to withstand high pulling forces. The other elements of flight deck boundary generally considered less vulnerable but still must satisfy the standards. The wall separating the flight deck from passengers (bulkhead) might already be strong enough to resist break-ins. If the flight deck wall is in front of other rooms like a kitchen or closet, those rooms and the space between them might also help keep people out. This all helps make the wall stronger. Flight deck doors and other boundary elements only one of the elements for security what must consist with other elements.

Standardization of Tests. For the test used a standard of National Institute of Law Enforcement and Criminal Justice (NILECJ), 0306.00 what released in May 1976 [5]. This standard describes performance requirements and methods of testing home and business doors and their components, it's used for typical entry doors for residence and small businesses. Four level of security and for tests in this aircraft taken the last level of security, but with increased demonstrated performance levels and for the testing there are four main types of door's elements which will be subjected for testing. They addressed to impact on the door, bolt, hinged and on the pulling for handles. The important information about testing recorded in table 3.1.

*Table 3.1*

**Parameters of the tests of door elements**

| № | Test | Measured Parameter | Requirements per NILECJ |
|---|---|---|---|
| 1 | Panel Impact | Impact resistance of door or boundary panel | 2 blows of 300 J |
| 2 | Bolt Impact | Impact resistance at bolt | 2 blows of 300 J |
| 3 | Hinge Impact | Impact resistance at hinge | 2 blows of 300 J |
| 4 | Pulling Test | Pulling resistance at doorknob or handle | A tensile load of up to 250 lb or until handle |

Test Equipment. For the intrusion check test used a ram pendulum system made by steel with at least 45 kg, what can do horizontal impact at least 300 Joules.

For this steel ram used cylinder with hemispherical done on the nose with diameter of approximately 15.2 cm and made like with epoxy-polyamide resin. This test must consist of representing airplane wall-frame structure with the door. The restraint provided by this fixture must simulate the rigidity provided in the airplane by the all airplane elements like walls and floor. The example of test frame of airplane wall structure is shown in figure 3.1.

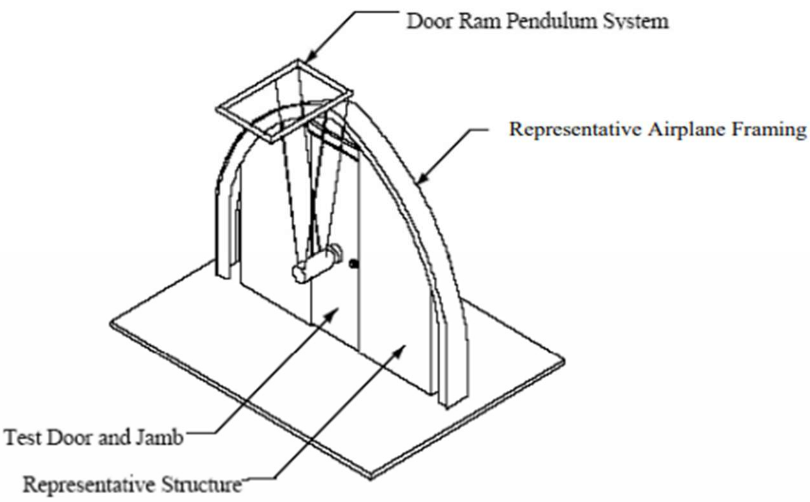



Fig. 3.1. Example of door assembly support.

Testing. For the door impact test the door should be closed, and the pendulum should be prepared to hit the most critical points for strength. This impact points may be defined by the intersection of the vertical centerline of the door and a line from the center of the bolt at the door edge to the center of the mid-height hinge, or the mid-point between hinges. For the bolt need prepare pendulum horizontal and perpendicular to the face of the door in bolt impact position. This point is close to bold and if doorknob is interfering impact, just take another point close to bold upper on lower doorknob. Carry out two blows to check the design, in case of deformation of the parts, this should be investigated and justified.

Assembly fail if: during the impact tests doors is be opened by the impact on hinged, bolt or by tensile load what applied to the knob/handle; if the person can easily enter from outside because after impact test on doors are present boundary or grasp; if door handle/knob is failure and effect on the closed door/help to open them, including usage of simple instruments like keys, credit cards, pocket knives.

### 3.2.2. Requirements of penetration resistance

These requirements mean the standards/tests for penetration resistance of flight deck doors and recommendation to design of the door for safe of pilot's and cockpit equipment.

Main Requirements of Regulation 25.795(2). Even though planes are safe, the part of flight deck when pilots is a weak spot. Guns or explosive devices could hurt the pilots and break the important systems and instruments what they need to operate the fly. Since everything to fly the plane is close together, one hit could ground the whole plane. Like displays what show important information is very vulnerability and can be easily taken out of order.

Parts of the pilot's area most at risk of being shot at or attacked with a hand grenade (from the passenger area) will be strengthened to stop bullets and shrapnel. The goal is to ensure that safe flight and landing. To shield pilots, key areas of the cockpit exposed to gunfire or grenades from passengers will be reinforced. This includes strengthening the main barrier (bulletproof panels) and, if needed, the floor and ceiling to stop bullets and shrapnel. Parts not directly in the line of fire won't require the same protection. Threats are considered only from passenger areas, not hidden compartments.

Things on the wall between the cockpit and passenger area, like air vents, handles, and peek holes, don't need special bullet-stopping tests if they wouldn't let bullets through even if they broke. This means they can't be in the direct line of fire or create a hole in the wall if they break.

To ensure optimal ballistic protection, joints between flight deck panels should exhibit minimal gaps. Ideally, these gaps should be eliminated. However, when unavoidable, these gaps require specific measures to maintain the overall ballistic resistance of the barrier.

Equivalent Material Protection: However, if the gap is properly filled with the ballistic tested equivalent material, then the gap is tested jointly with the filler, and it perhaps does not need individual testing. Likewise, where protective materials butt join may be acceptable without testing when they meet squarely and the ways in which the impact occurs must be essentially benign as must be the effect of the ballistic impact on the protective material's resistance.

Testing Requirements for Gaps: As for the cases when gap testing is necessary, specific pass / fail criteria that have been set up for certain specific ballistic tests for material would be relevant. But, in general, if the gap does not have the critical orientation with a very limited region of angle, then a single shot having a normal orientation with the surface would be adequate for the test.

Technique of test. Testing angle: Flight deck barriers require to be strong enough to contain bullets that can come from any angle but direct. This is because actual assailants can shoot in specific angles compared to shooting perpendicularly in which some protective materials may minimize by as much as twenty percent. This test aims to confirm that the material provides the minimum protection necessary to protect an individual's head from an impact made from any angle.

To get good reliable readings from flight deck barriers, which are to be smooth and constant, with no bumps, gaps or areas of weakness, readings from only two tests, that at zero-degree angle (straight on) and 30-degree angle are usually adequate. There is no need to test at the additional angles in this case. The presence of such structural breaks such as high gaps or rough sur faces, for example the ones shown in figure 3.2, complicates the otherwise seamlessly defined system. These weak points must be considered when carrying out the tests. Even if the cloth consists of primary ballistic materials that protect against bullets, if the discontinuity forms a path for a bullet to pass through the main mass and get to the flight deck, the whole barrier is deemed to have been shot-through. This means that even regions adjacent to flaws provide the desired degree of protection.

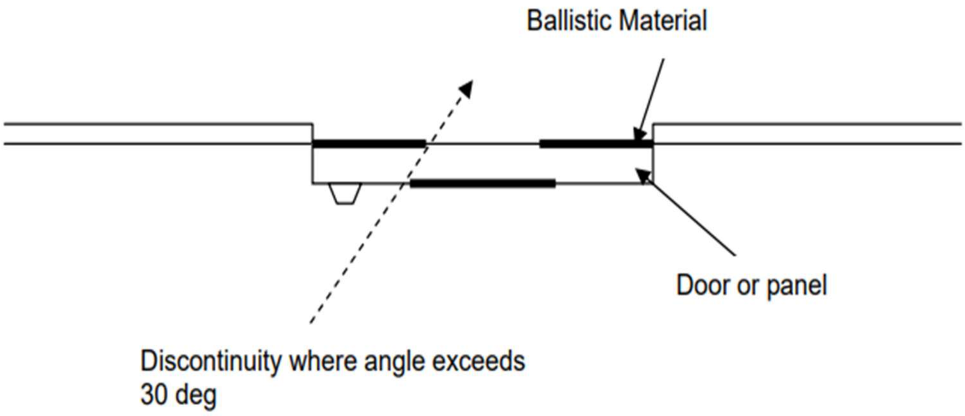



Fig. 3.2. Example of the gaps.

Main criteria of test. Armor Standards. The established national body armor performance standards developed by the National Institute of Justice (NIJ) under the U.S. Department of Justice. Specifically, the minimum performance requirements and compliance demonstration methods outlined in AC 25.795-2A are based on the widely recognized NIJ Standard-0101.04, "Ballistic Resistance of Personal Body Armor," published in September 2000 [3].

Protection level: The National Institute of Justice (NIJ) has created a system to rate body armor protection using different levels. To meet the safety requirements § 25.795(a). [4], level IIIA is the minimum acceptable protection. This level stops bullets from most handguns and also offers some protection from explosions and other things that could cause shrapnel. Level IIIA is tougher than levels I, II, and IIA. To make sure armor meets this level, it's tested with two specific types of bullets.

First is a 9 mm full metal jacket, round nose bullet with mass of 8.0g and reference velocity 436 m/s.

Second is A .44 Magnum, jacketed hollow point bullet with mass of 15.6 g and reference velocity 436 m/s. Test bullets and weapon recorded in table 3.2.

*Table 3.2*

**Characteristics of test bullets**

| Test Round | Test Bullet | Weight | Diameter | Velocity | Hits at 0 Angle | Hits at 30 Angle | Hits at 45 Angle | Total shots |
|---|---|---|---|---|---|---|---|---|
| 1 | 9 mm FMJ RN | 8 g | 9 mm | 436 m/s | 4 | 2 | 6 | 12 |
| 2 | .44 Magnum JHP | 15.6 g | 10.9 mm | 436 m/s | 4 | 2 | 6 | |

Timing screens: Projectile impact velocities will be measured on every test. Any systems that can measure velocities to within 3 m/s are acceptable. Individual recording devices must be capable of discriminating to 0.3 m/s or 0.1 microseconds. Example of timing screens and test demonstrated on figure 3.3.

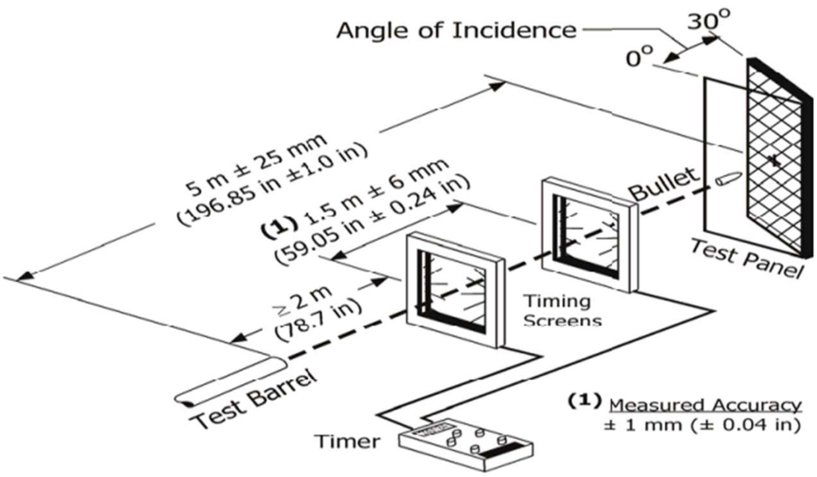



Fig. 3.3. Example of Penetration Test and timing screens.

Test Shots: As shown in Table 1, two types of ammunition shall engage in the test. In both cases, specimens of each type will be shot at labelled impact points on one of the test panels. They will shoot two impacts, out of every six shot sequence from an angle of 30 degrees. After each individual shot, the test panel will be analyzed to establish the extent of complete projectile arrest. Arising from this evaluation, a pass or fail grade shall be recorded against each of the impacts mentioned above as appropriate. A specific velocity of the projectile upon impact will in turn be measured and logged during each test. In the light of the above facts, measured velocity below the preset minimum acceptable value or impact point outside the prescribed region may call for repetition of the test. The elaborated shooting between shares appears to allow the projectile removal for exact check, but it is not compulsory.

Witness Plate: A witness plate made of an appropriate material will be fixed at 15 centimeters to the rear of the test article. This plate needs to ensure that no further penetration has taken place, by the projectile or any fragments of it.

Pass and fair criteria. The shoots are valid if:

- the bullet must strike the panel within ±5 degrees of the intended angle of incidence;
- the bullet's yaw angle (rotational alignment) must be within ±5 degrees of its intended orientation upon impact;
- the bullet's velocity at impact must fall within ±9.1 m/s of the reference velocity;
- the point of impact must adhere to minimum distance requirements from edges;
- when aiming for specific features on the panel, the bullet must directly hit the intended feature.

Test results are successful if all of the pre-determined test conditions are met and the impact velocity is equal to or higher than the minimum required figure without penetrating the panel that divides the cabin from the flight deck.

Test results are fail if any penetration that which results in total or partial loss of structural barrier between the cabin and the flight deck such as in the panels and or the grills. This includes cases where the impact velocity is adequate to release kinetic energy beyond the minimum established threshold but results in breaches.

Test Outcome Determination. Failure: They pointed out that the penetration of the barrier occurs independent of the impact velocity. It remains applicable to cases where the ultimate impact velocity is not exceeded at particular landing sites like in the case of large tanks. Possible Retest: However, for validation of a single simulation point where all of the above conditions are satisfied except penetration, a retest may be allowed even if the impact velocity exceeds the maximum permissible value allowed for the design on some counts.

### 3.3. Flight deck doors design

Examples of bullet-proof doors from the Antonov and Airbus companies were used to develop the door design for the aircraft. The 3D design was developed using the SolidWorks CAD system, taking into account the requirements and recommendations of specialists, receiving during pre-diploma practice at the Antonov Enterprise. The complete Assembly Design in front view or from passenger side is shown in figure 3.4 and inner part from flight deck in figure 3.5

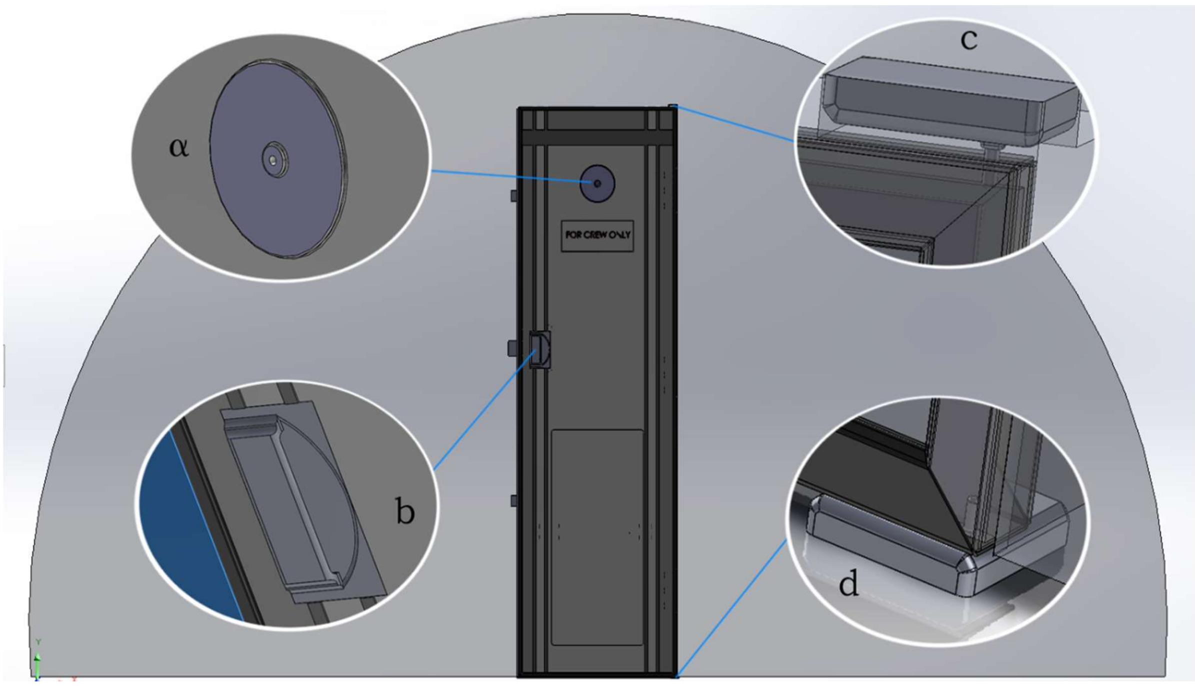



Fig. 3.4. Design of door assembly front view from passenger side:
*a* – peephole; *b* – handle; *c* – upper hidden hinged; *d* – lower hidden hinged.

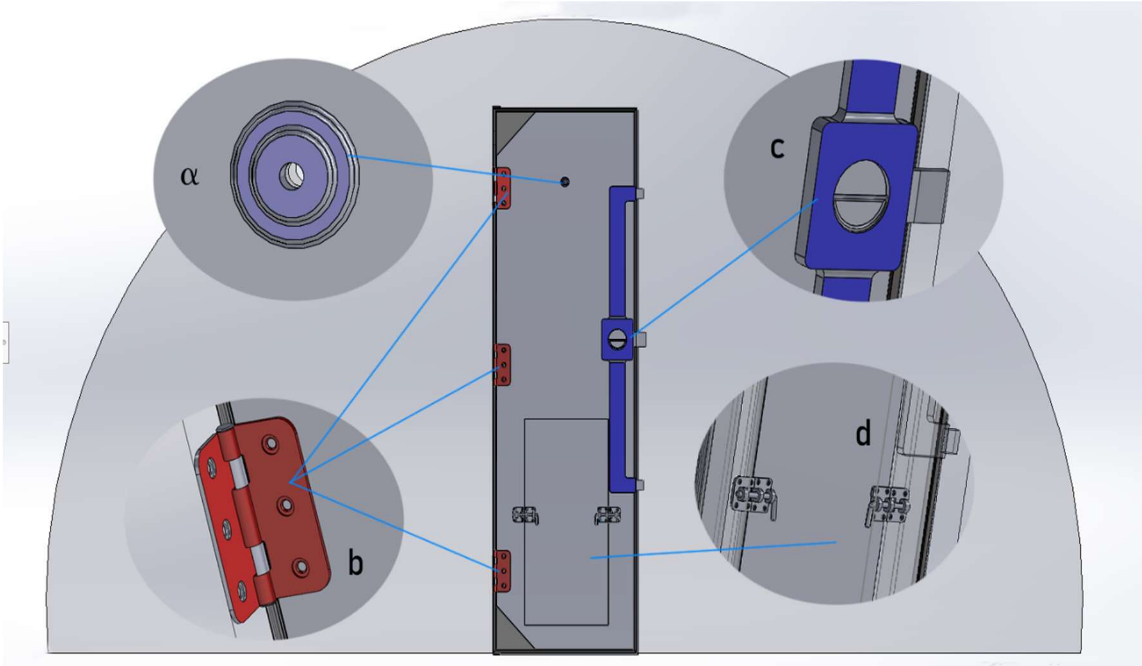



Fig. 3.4. Design of door assembly inner part from flight deck:
*a* – inner peep hole; *b* – hinge; *c* – triple bolt; *d* – removable panel.

Hinges: In its design, the cockpit door hinges are very important since they will determine the type of operations that will be performed on the door. These are strong, accurate parts made using machine operations that connect the door to the surrounding airplane structure. Non-swinging doors, for instance, have hinges that enable the door to move freely in the right direction and still easily open or close which rather provides easy access to the crew apart from assisting enhance the structure of the barrier. Their damage will lead to the intrusion of unauthorized persons into the cockpit, and this cannot be allowed, so their design must be reliable. The best material for manufacturing is hardened steel or aluminum. An example of the hinges used and their location is shown in figure 3.4 (b), as well as additional strengthening in figure 3.3 (c)(d).

Bolt locker: Is one of the critical components that enhance proper working of the bullet-proof cockpit door. This is a main locking system with locking handles located in the flight deck and intended to be work by the pilots and crew. Involves a severable strong metallic bolt which upon triggering fires into a held designated reception in the airplane frame. This establishes a very strong latch point that also greatly enhances the door with respect to its ability to resist possible attempts at forcing it open. This design uses an electronic version of the triple bolt, which is shown in figure 3.4 (c).

Handle of a bullet-proof cockpit door is not only relevant but rather significant in maintaining the competency of the flight deck. Unlike an ordinary door handle that focuses its user and ergonomic considerations on how easy and comfortable it is to turn the handle, the cockpit door handle presents a combination of safety and convenience. But in this design handle it’s just one of the reinforce element and just for open/close the door. Handle and location is shown in figure 3.3 (b).

Although the primary purpose of a bullet-proof cockpit door is to provide safety and security, it is equally important for the crew to be aware of what is happening behind the door. This peephole also may be replaced by cameras. Peephole shown in figure 3.3 (a) like from forward strengthened part and inner part in figure 3.4 (a).

The removable panel is designed in the event that the door cannot be opened in the event of the bolt's electronics being closed, or the door itself malfunctioning, so that the aircraft crew can leave the cockpit in an emergency by removing this panel. The panel is shown in figure 3.4 (d).

### 3.4. Bullet-proof panel design and stress-strain analysis

The options for the mitigation of ballistic threats available at the present moment have been analyzed. The main useful materials to incorporate are metallic alloys, ceramics, polymers, strong fibers, or composites. This is because strong fibers usually in the form of a compressed or woven fabric and which are sometimes coated by a matrix material often provide the best kind of protection for lightweight and relatively low-energy application. From the considered examples of armor-piercing doors from Antonov and Airbus, the best choice is still the Airbus version with composite doors, rather than titanium doors from Antonov. The Airbus doors benefit from their compactness and weight, as the Antonov doors are made of titanium alloy and a chair is attached to them, which is not part of design. The choice of composite material is due to its lightness and reliability. If talk more detailed, for bullet-proof will be used ultra-high molecular weight fibers that are of a very dense and treated with epoxy resins. This reinforced method shown in figure 3.5

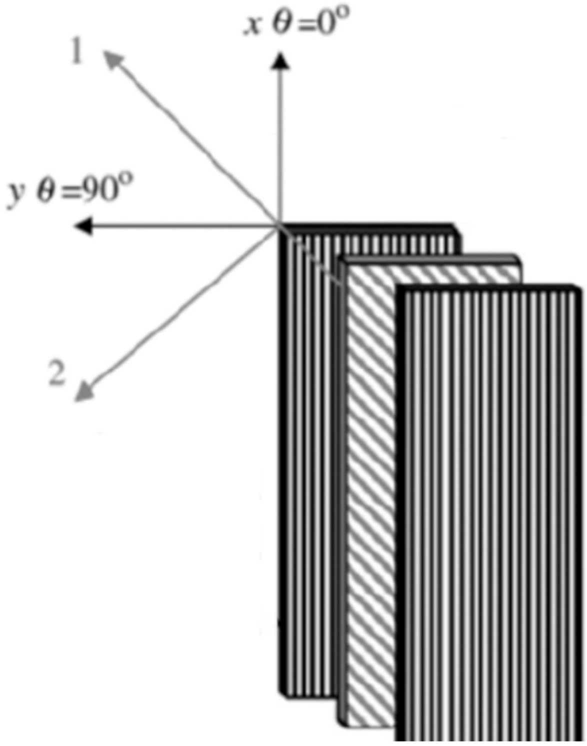



Fig. 3.5. Method of reinforcement composite.

As shown in figure 3.5, the protective panel for the door consists of three different layers of ultra-high molecular weight polyethylene with epoxy resin as a matrix, the characteristics used in the analysis were recorded in table 3.3. The panel itself together with U.H.M.W. polyethylene and epoxy resin reaches 10 mm as shown in figure 3.6. Each subsequent layer of material is applied at different angles, as the angle affects the characteristics of the composite. When fibers are arranged in one direction, there are fewer obstacles for the projectile to overcome, however, when fibers are arranged in another direction, it is even harder for a projectile to penetrate through the material. For example, attempt to visualize the process of packing a punch through a typical woven basket as opposed to an ordinary ball of yarn wrapped up very tightly. This is due to the fact that a large number of fibers are set at an angle such that it forms a complex network of tunnels, making it difficult for the projectile to pass through without changing its direction. This absorb the projectile energy and ensures a higher chance of the projectile being knocked off before penetrating the armor. And also oriented at angle four fibers possess higher shear strength than those existing in a single direction. Shear strength is the third parameter of a material, which measures the ability of a material to withstand forces that seek to push it apart in a perpendicular directional sense. If the fabric is hit by a projectile it exerts a shearing force on the fibers in the armor.

*Table 3.3*

**Data for Analyze of UHMWP panel**

| Notation | Properties | Magnitude |
|---|---|---|
| $E_{11}$ | Young’s modulus (kPa) | $3.62 \times 10^6$ |
| $E_{22}$ | Young’s modulus (kPa) | $5.11\times10^7$ |
| $E_{33}$ | Young’s modulus (kPa) | $5.11\times10^7$ |
| $v_{12}$ | Poisson's Ratio | 0.43 |
| $v_{13}$ | Poisson's Ratio | 0.5 |
| $v_{23}$ | Poisson's Ratio | 0.43 |
| $G_{12}$ | Shear modulus (GPa) | 2 |
| $G_{13}$ | Shear modulus (GPa) | 2 |
| $G_{23}$ | Shear modulus (GPa) | 2 |
| σ | Ultimate strength (MPa) | 2800-3200 |
| ρ | Density (kg/m$^3$) | 970 |
| T | Reference temperature (K) | 293 |

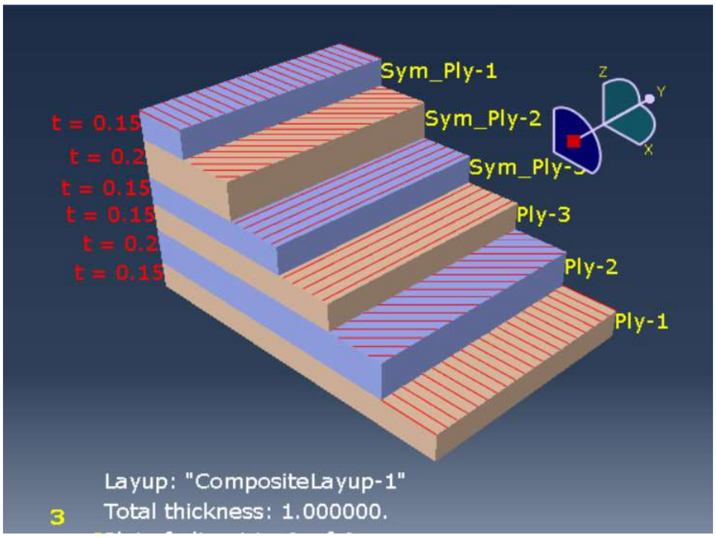



Fig. 3.5. Example of Composite Panel model in Abacus.

For the test, the upper part of the bullet with a given mass of 8 grams (Figure 3.6) was simulated with the speed indicated in the requirements for interaction with the composite panel, which is a plate as in figure 3.5 with the used characteristics for UHMWP [11]. The result of the collision is shown in figure 3.7 according to Mises until the moment when the ball began to lose energy. Test was performed in Abaqus CAE.

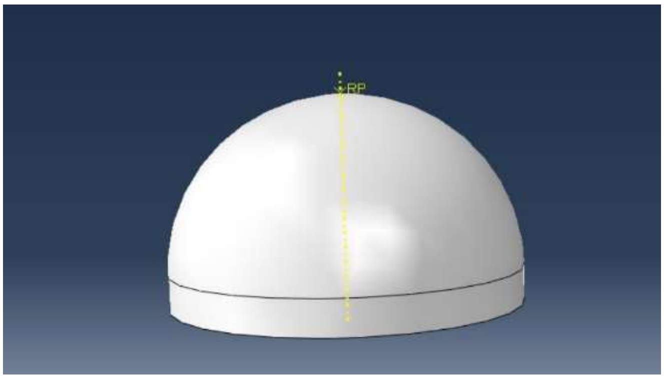



Fig. 3.6 Model of upper part of bullet

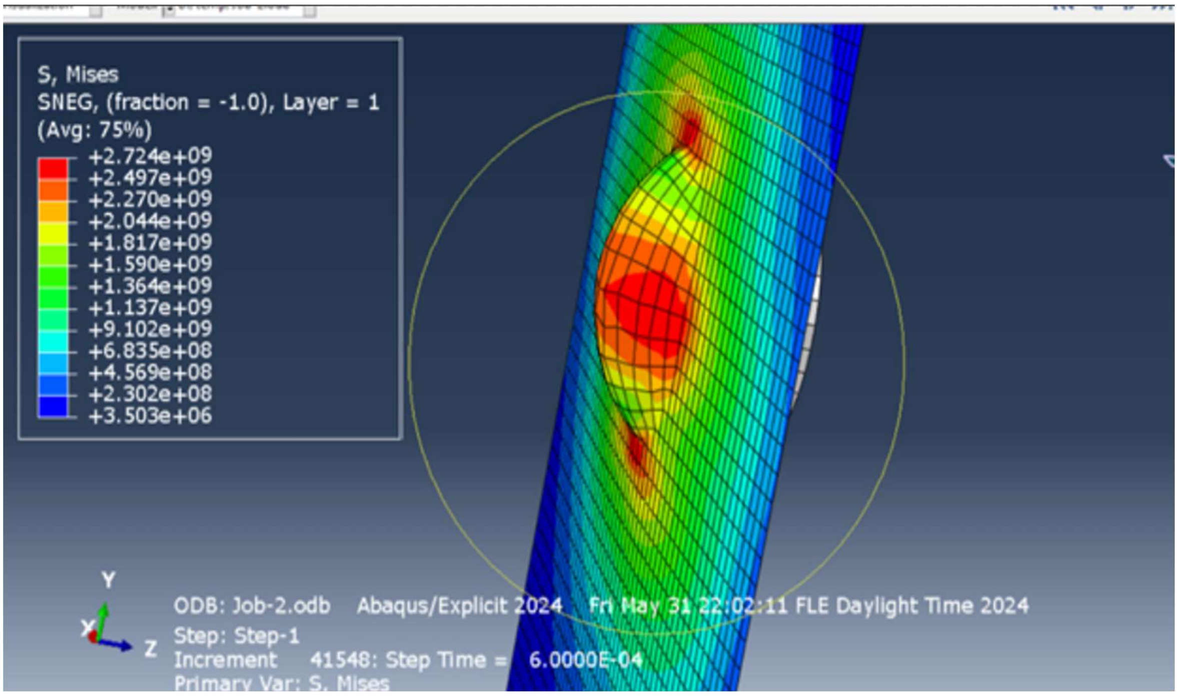



Fig. 3.7. Analyzes composite panel in Mises.

From the results of the elastically deformed state of the aircraft door panel. This analysis revealed that the maximum stress of 2724 MPa was concentrated in the central region of the deformed panel. Thankfully, this peak stress value falls well within the allowable stress limits established for the chosen material as outlined in Table 3.3.

These findings strongly suggest that the combination of the selected materials and the panel's methodic of construction effectively guarantees the door's structural integrity in the analyzed section, meeting the stringent strength.

It is important to acknowledge that for a more thorough understanding of the panel's performance under real-world conditions, practical testing with an armored panel crafted from UHMWPE (Ultra-High Molecular Weight Polyethylene) is warranted. Such testing would provide valuable insights to complement the current analytical data.

**Conclusions to the special part**

The safety of passengers and pilots on the plane is very important to understand due to critical situations that may arise. Armored doors are an important element of safety on board that prevents capture and ensures safety for pilots and important equipment. The design of it plays a significant role, especially the design of the protective panel, which prevents the door from being shot if a firearm is brought on board.  The best option for a bullet-proof door was a composite material with epoxy resin and ultra-high molecular weight fiber, and an analysis was carried out that showed that a 9mm bullet could not penetrate the 3 specified layers and don't give a needed stress to penetrate the armor. The composite material shows itself well as it is much lighter than alloys, while it does not lose its stability and is as strong as the alloys that are used and have been used for armored doors.

## GENERAL CONCLUSIONS

1. At the end of this project, a prototype of a short-medium distance aircraft based on the Comac C919 was developed, taking into account various needs and requirements. The main dimensions were calculated: the mean aerodynamic chord $b_{MAC}$ = 3.64 m, Fuselage length is equal to 38.88 m, chosen 210 MPH D 34×9.25-16 for nose landing gear and 225 MPH D H46×18.0-20 for main landing gear and the design was developed and shown in drawings. The LEAP-1C engines were selected like the best variant for the mid-range aircraft during to the performance.

2. The aircraft layout was performed. The design of galleys and lavatories was developed and located. Main drawing of layout was performed with compliance with all requirements. Cente of gravity range: the most forward is 18% from the leading edge of mean aerodynamic chord in parking version and a maximum aft position in take-off mass with 27%.

3. In a special part, the requirements for cockpit doors was analyzed, as well as the current requirements for the level of protection of bulletproof doors. The design was developed on the basis of the SolidWorks CAD system, focusing on the doors from prototypes of the Antonov and Airbus companies. The most suitable material was selected and a test was carried out on the bullet proofness of the protective plate made of composite material that can be used to protect the door. After analyses of armored panel of UHMWP what used for door and modeling high-impact test in program Abaqus CAE, the data has been received, maximum stress was 2724 MPa and material have the ultimate strength in range from 2800 to 3200.

## REFERENCES


1. Ali Bahrami. Federal Aviation Administration, Advisory circular 25.795-1A; 10/24/08, Available from: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_25_795-1A.pdf
2. Ali Bahrami. Federal Aviation Administration, Advisory circular 25.795-2A; 10/24/08, Available from: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_25_795-2A.pdf
3. Ballistic Resistance of Personal Body Armor, NIJ Standard-0101.04, September 2000, Available from: https://nij.ojp.gov/library/publications/ballistic-resistance-personal-body-armor-nij-standard-010104
4. Federal Aviation Administration 14 CFR § 25.795 - Security considerations. Available from: https://www.law.cornell.edu/cfr/text/14/25.795
5. Law Enforcement and Criminal Justice (NILECJ), 0306.00, released in May 1976. Available from: https://www.ojp.gov/pdffiles1/nij/32269.pdf
6. Germanwings Flight 9525 catastrophe. Available from: https://en.wikipedia.org/wiki/Germanwings_Flight_9525
7. Federal Aviation Administration, Advisory circular 25.785 ; 10/24/08, Available from: https://www.law.cornell.edu/cfr/text/14/25.785
8. Конструкція та міцність літальних апаратів (частина 1): методичні рекомендації до виконання курсового проекту для студентів спеціальності 134 «Авіаційна та ракетно-космічна техніка» /уклад.: С.Р. Ігнатович, М.В. Карускевич, Т.П. Маслак, С.В. Хижняк, С.С. Юцкевич. – К.: НАУ, 2018. – 91с.
9. SolidWorks Simulation Online Help - Dassault Systèmes.

10. Long, H.N.; Ryan, S.; Cimpoeru, S.J.; Mouritz, A.P.; Orifici, A.C. The effect of target thickness on the ballistic performance of ultra high molecular weight polyethylene composite. *Int. J. Impact Eng.* 2015, *75*, 174–183.

11. **Chicago/Turabian Style**

Ding, Li, Xiaohui Gu, Peihui Shen, and Xiangsheng Kong. 2022. "Ballistic Limit of UHMWPE Composite Armor under Impact of Ogive-Nose Projectile" *Polymers* 14, no. 22: 4866. https://doi.org/10.3390/polym14224866

# APPENDIX

# APENDIX A

INITIAL DATA AND SELECTED PARAMETERS

Passenger Number - 174

Flight Crew Number - 2

Flight Attendant or Load Master Number -6

Mass of Operational Items -1697.40 kg

Payload Mass -18287.50 kg

Cruising Speed – 834 km/h

Cruising Mach Number -0.7793

Design Altitude – 10.7

Flight Range with Maximum Payload - 4500 km

Runway Length for the Base Aerodrome – 2.95

Engine Number - 2

Thrust-to-weight Ratio in N/kg – 3.3600

Pressure Ratio -32.8

Assumed Bypass Ratio -6.50

Optimal Bypass Ratio -6.50

Fuel-to-weight Ratio -0.13

Aspect Ratio – 8.78

Taper Ratio – 4.00

Mean Thickness Ratio – 0.118

Wing Sweepback at Quarter Chord -27*

High-lift Device Coefficient -1.050

Relative Area of Wing Extensions

Wing Airfoil Type –Supercritical

Winglets - yes

Spoilers - yes

Fuselage Diameter – 3.96

Finess Ratio -9.82

Horizontal Tail Sweep Angle -30*

Vertical Tail Sweep Angle -35*

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point -0.44363

Induce Drag Coefficient -0.00914

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

Cruising Mach Number – 0.77930

Wave Drag Mach Number – 0.78734

Calculated Parameter $D_m$ – 0.00804

Wing Loading in kPa (for Gross Wing Area):

At Takeoff – 5.188

At Middle of Cruising Flight -4.497

At the Beginning of Cruising Flight – 5.002

Drag Coefficient of the Fuselage and Nacelles – 0.00963

Drag Coefficient of the Wing and Tail Unit -0.00916

Drag Coefficient of the Airplane:

At the Beginning of Cruising Flight – 0.02997

At Middle of Cruising Flight – 0.02895

Mean Lift Coefficient for the Ceiling Flight – 0.44363

Mean Lift-to-drag Ratio – 15.32408

Landing Lift Coefficient – 1.616

Landing Lift Coefficient (at Stall Speed) – 2.424

Takeoff Lift Coefficient (at Stall Speed) -1.999

Lift-off Lift Coefficient – 1.460

Thrust-to-weight Ratio at the Beginning of Cruising Flight -0.608

Start Thrust-to-weight Ratio for Cruising Flight -2.505

Start Thrust-to-weight Ratio for Safe Takeoff -2.637

Design Thrust-to-weight Ratio – 2.743

Ratio $D_r = R_{cruise} / R_{takeoff}$ = 0.950

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

Takeoff – 33.4823

Cruising Flight – 56.5294

Mean cruising for Given Range – 58.8557

FUEL WEIGHT FRACTIONS:

Fuel Reserve – 0.03457

Block Fuel – 0.22206

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing - 0.10554

Horizontal Tail – 0.01104

Vertical Tail - 0.01089

Landing Gear – 0.04019

Power Plant – 0.08707

Fuselage – 0.08820

Equipment and Flight Control – 0.13653

Additional Equipment – 0.01364

Operational Items – 0.02126

Fuel – 0.25663

Payload – 0.22910

Airplane Takeoff Weight = 79822

Takeoff Thrust Required of the Engine = 109.46

Air Conditioning and Anti-icing Equipment Weight Fraction – 0.0235

Passenger Equipment Weight Fraction – 0.0177

(or Cargo Cabin Equipment)

Interior Panels and Thermal/Acoustic Blanketing Weight Fraction – 0.0078

Furnishing Equipment Weight Fraction – 0.0135

Flight Control Weight Fraction – 0.0064

Hydraulic System Weight Fraction – 0.0175

Electrical Equipment Weight Fraction – 0.0323

Radar Weight Fraction – 0.0031

Navigation Equipment Weight Fraction - 0.0047

Radio Communication Equipment Weight Fraction – 0.0023

Instrument Equipment Weight Fraction – 0.0055

Fuel System Weight Fraction – 0.0075

Additional Equipment:

Equipment for Container Loading – 0.0088

No typical Equipment Weight Fraction – 0.0049

(Build-in Test Equipment for Fault Diagnosis,

Additional Equipment of Passenger Cabin)

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed – 271.37 km/h

Acceleration during Takeoff Run – 2.05 m/s$^2$

Airplane Takeoff Run Distance – 1384 m

Airborne Takeoff Distance – 578 m

Takeoff Distance – 1963 m

CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed – 257.80 km/h

Mean Acceleration for Continued Takeoff on Wet Runway – 0.17 m/s$^2$

Takeoff Run Distance for Continued Takeoff on Wet Runway – 2882.40 m

Continued Takeoff Distance – 3460.77 m

Runway Length Required for Rejected Takeoff – 3587.85 m

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight – 65761 kg

Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight – 21.1 minutes

Descent Distance – 48.91 km

Approach Speed – 251.74 km/h

Mean Vertical Speed – 2.03 m/s

Airborne Landing Distance – 518 m

Landing Speed -236 km/h

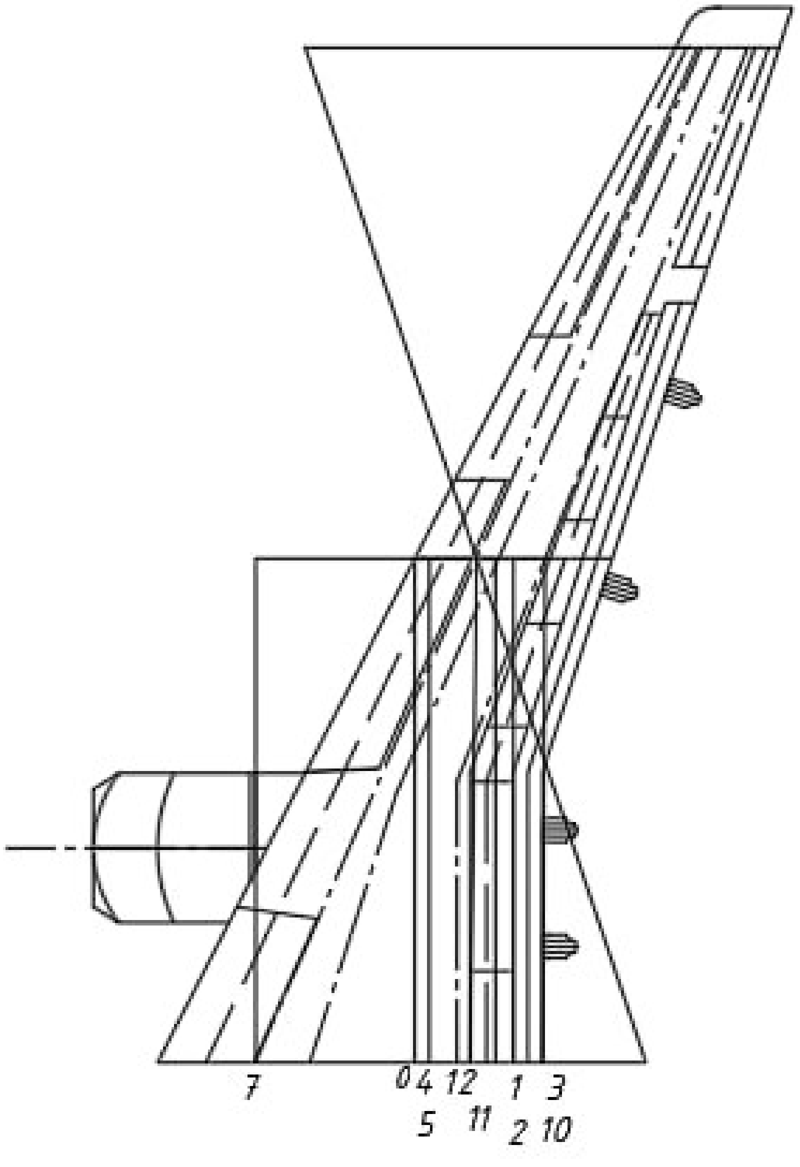
Landing run distance – 718 m

Landing Distance – 1286 m

Runway Length Required for Regular Aerodrome – 2147 m

Runway Length Required for Alternate Aerodrome – 1826 m

Appendix B




| | | | | |
|---|---|---|---|---|
| Ch. | Sheet | Document № | Sign. | Date |
| Performed | | Prykhodko A.E. | | |
| Supervisor | | Maslak T.P. | | |
| Tech. Control | | | | |
| | | | | |
| St. Controler | | Krasnopolskyi V.S | | |
| Approved | | Yutskevich S.S. | | |

NAU 24 07P 00 00 00 80 EN

Center of gravity of the wing

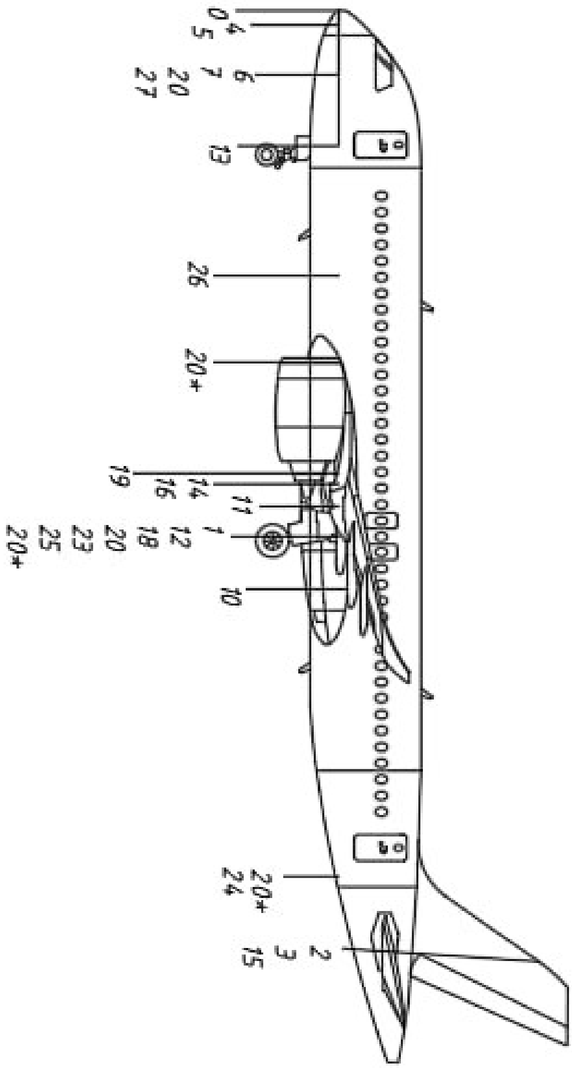
| Letter | Weight | Scale |
|---|---|---|
| Q | | 1:50 |
| Sheet 1 | | Sheet 2 |

Appendix B

404 ASF 134

# APENDIX C

## Appendix C




NAU 24 07P 00 00 00 80 EN

| Ch. | Sheet | Document № | Sign. | Date |
|---|---|---|---|---|
| Performed | | Prykhodko A.E. | | |
| Supervisor | | Maslak T.P. | | |
| Tech. Control | | | | |
| | | | | |
| St. Controler | | Krasnopolskyi V.S. | | |
| Approved | | Yutskevich S.S. | | |

| Title | Letter | Weight | Scale |
|---|---|---|---|
| Center of gravity of the fuselage | Q | | 1:100 |
| | Sheet 1 | Sheet 2 | |
| Appendix C | 404 ASF 134 | | |