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

ДОПУСТИТИ ДО ЗАХИСТУ
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КВАЛІФІКАЦІЙНА РОБОТА
ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ
«БАКАЛАВР»

Тема: «Види, методика та розробка заклепувалих з'єднань обшивки літака»

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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: "Types, methods and development of riveted joints of aircraft skin"

Fulfilled by: ____________ **Volodymyr HEILENKO**

Supervisor:
PhD, associate professor ____________ **Yuriy VLASENKO**

Standards inspector:
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, д.т.н, проф.
__________ Святослав Юцкевич
«___» ____________ 2024 р.

ЗАВДАННЯ

на виконання кваліфікаційної роботи здобувача вищої освіти

ГЕЙЛЕНКА ВОЛОДИМИРА ВОЛОДИМИРОВИЧА

1. Тема роботи: «Види, методика та розробка заклепувалих з'єднань обшивки літака», 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: маса комерційного навантаження 82867 кг, дальність польоту з максимальним комерційним навантаженням 18000 км, крейсерська швидкість польоту 878 км/год, висота польоту 12 км.
4. Зміст пояснювальної записки: вступ, основна частина, що включає аналіз літаків-прототипів і короткий опис проектованого літака, обґрунтування вихідних даних для розрахунку, розрахунок основних льотно-технічних та геометричних параметрів літака, компонування пасажирської кабіни, розрахунок центрування літака, спеціальна частина, яка містить дослідження та розробку заклепувальних з’єднань обшивки літака.
5. Перелік обов’язкового графічного (ілюстративного) матеріалу: загальний вигляд літака (А1×1), компонувальне креслення фюзеляжу (А1×1), розрахункові графіки і діаграми.

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	Огляд літератури за проблематикою роботи. Аналіз з’єднань в каркасі літака.	28.05.2024 – 29.05.2024	
6	3D моделювання частини обшивки з деталями каркасу	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 ____________ Юрій ВЛАСЕНКО

Завдання прийняв до виконання ____________ Володимир ГЕЙЛЕНКО

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,
Professor Dr. of Sc.
_____Sviatoslav YUTSKEVYCH
"___" ____________ 2024

TASK

for the bachelor degree thesis

Volodymyr HEILENKO

1. Topic: " Types, methods and development of riveted joints of aircraft skin", approved by the Rector's order order № 794/ст from 15 May 2024..
2. Period of work: since 20 May 2024 till 16 June 2024.
3. Initial data: payload 82.8 tons, flight range with maximum capacity 18000 km, cruise speed 878 km/h, flight altitude 12 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, a special part that includes the research and development of riveted joints for aircraft skins.
5. Required material: general view of the airplane (A1×1), layout of the airplane (A1×1), schemes, plots and diagrams.

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	Analysys of joints in the aircraft structure	28.05.2024 – 29.05.2024	
6	3D modeling of aircraft skin part attached to the frame of the aircraft	30.05.2024 – 31.05.2024	
7	Analysis of experimental data and fatigue crack growth dependences.	30.05.2024 – 31.05.2024	
8	Explanatory note checking, editing, preparation of the diploma work graphic part.	01.06.2024 – 02.06.2024	
9	Submission of the work to plagiarism check.	03.06.2024 – 06.06.2024	
10	Preliminary defense of the thesis.	07.06.2024	
11	10 Making corrections, preparation of documentation and presentation.	08.06.2024 – 10.06.2024	

7. Date of the task issue: 20 May 2024

Supervisor: ____________ Yuriy VLASENKO

Student: ____________ Volodymyr HEILENKO

РЕФЕРАТ

Пояснювальна записка кваліфікаційної роботи бакалавра «Види, методика та розробка заклепувалих з'єднань обшивки літака»:

57 с., 20 рис., 4 табл., 11 джерел

Дана кваліфікаційна робота присвячена розробці пасажирського далекомагістрального літака з можливістю транспортування вантажу, який відповідає міжнародним нормам безпеки, економічності та надійності, а також аналізу заклепувальних з’єднань в обшивці літака.

В роботі було використано методи аналітичного розрахунку, компьютерного проєктування за допомогою CAD/CAM/CAE систем.

Практичне значення результату кваліфікаційної роботи полягає в доцільності використання заклепок як виду з`єднання, та порівнювання переваг та недоліків з іншими видами.

Матеріали кваліфікаційної роботи можуть бути використані в навчальному процесі та в практичній діяльності конструкторів спеціалізованих проектних установ.

Дипломна робота, аванпроект літака, компонування, центрування, обшивка літака

ABSTRACT

Bachelor degree thesis "Types, methods and development of riveted joints of aircraft skin"

57 pages, 20 figures, 4 tables, 11 references

This work is a preliminary design of a passenger aircraft for long-haul with the possibility of transporting cargo which adheres to the international regulatory standards for flight, safety, economy and reliability, and an analysis of riveting in aircraft skin.

In the design methodology the prototype analysis was used to choose the best technological solutions, engineering calculations to get the technical parameters of the designed aircraft and computer aided design using the CAD systems.

Practical value of the work is is the expediency of using rivets as a type of connection, and comparing the advantages and disadvantages with other types.

The materials of the qualification work can be used in the aviation industry and educational process of aviation specialties.

Bachelor thesis, preliminary design, cabin layout, center of gravity calculation, aircraft skin

Format	№	Designation	Name	Quantity	Notes
			<u>General documents</u>		
A4	1	NAU 24 13H 00 00 00 02 TW	Task for work	1	
	2	NAU 24 13H 00 00 00 02 LD	Long-range passenger aircraft	2	
A1		Sheet 1	General view		
A1		Sheet 2	Fuselage layout		
A4	3	NAU 24 13H 00 00 00 02 EN	Long-range passenger aircraft	57	
			Explanatory note		

	Sh.	№ doc.	Sign	Date	NAU 24 13H 00 00 00 02 EN			
Done by		Heilenko.V.V.			Types, methods and development of riveted joints of aircraft skin (List of diploma work)	list	sheet	sheets
Supervisor		Vlasenko Y.V.				Q	9	57
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St.control.		Krasnopolskiy V.S.						
Head of dep.		Yutskevych S.S.						

CONTENT

INTRODUCTION

In modern aircraft design, one of the most important parameters is weight and strength. These parameters are affected by many elements and factors, from the number of parts to the type of materials. Weight affects not only flight performance, but also the profitability of exploitation, for example, with less weight, there will be less fuel consumption, which will make the aircraft cheaper to operate. Strength is also an extremely important parameter, with greater strength, there is less chance of damage to the aircraft during the flight.

Mostly rivets are used in the frame joints, and they have proven themselves over time in terms of reliability. However, in addition to rivets, there are other types of connections that allow elements to be fastened together without the use of other parts. Welded joints, for example, add less additional weight and are also faster to install than rivets. Both of these types of connections have their advantages and disadvantages.

1. PRELIMINARY DESIGN OF LONG-RANGE AIRCRAFT

1.1 Analysis of prototypes and short description of designed aircraft

Table 1.1.

Parameters	Airplanes		
	B737	A320	A319
The purpose of airplane	Passenger	Passenger	Passenger
Crew/flight attend persons	2/4	2/4	2/4
Maximum take-off weight, kg	79 000	79 000	82867
Maximum payload, kg	20 540	20 000	17 937
Passengers	189	189	156
The flight altitude, m	12 497	12 100	12 100
Flight range, km	5 400	6 850	6 940
Takeoff distance, m	2 800	2 400	1 850
Number and type of engines	2 x CFMI CFM56-7B24/26	2 x CFMI Leap-1A	2 x CFM56-5B
The shape of the fuselage cross-section	circular	circular	circular
Finess ratio	10.5	11.8	8.57
Sweepback angle at 1/4 chord line	25	25	28

1.2. Classification of your designing aircraft according to the flight performances and layout.

Structurally, the airplane is divided into the following parts:

-Caisson wing (two spars);

-Fuselage (including a pressurized cabin for the crew and passengers);

-Horizontal and vertical tail unit;

-Power plant with a turbofan;

-Landing gear;

1.2.1 Fuselage

Its design leverages a range of lightweight, yet incredibly robust alloys and composite materials, giving it a significant advantage over other contemporary aircraft. Composite materials are used to make aerodynamic fairings, floor beams in passenger cabins, and other components. Nine percent of the weight of the entire airplane construction is made up of composite materials. As a result, the aircraft's weight and manufacturing costs are considerably.

1.2.2 Crew cabin

The arrangement of the cockpit and the placement of the primary and backup controls must permit crew members to operate the aircraft without undue strain or exhaustion.

The following are general ergonomic requirements: the handles and levers that pilots use the most should be placed in the most convenient working area; other handles and levers should be accessible and, if at all feasible, visible.

Two or three persons make up the crew of a modern passenger aircraft: two pilots or two pilots plus a flight engineer. The workstations of flight engineers are typically positioned between the pilots because of the increasing usage of displays on instrument panels in recent times.

1.2.3 Passenger furnishing

These aircraft have a pleasant and comfortable interior that includes power outlets for mobile devices, widescreen displays so you can watch the onboard entertainment system, and comfy armchairs. Depending on the degree of service, each passenger receives complete hot meals and excellent service.

While there aren't any outlets available, each seat has a USB port that allows passengers to charge their mobile devices. These ports are situated beneath the monitors. The screens have a regular audio connection installed, so you don't need an adaptor to use your headphones.

1.2.4 Landing gear

The purpose of the two-wheel bogies is to disperse the aircraft's load over a large area without the need for additional centerline gear. This lessens weight and streamlines the hydraulic and brake systems of the airplane.

1.2.5 Wardrobes

Close to the passenger compartment, by the entrance and exit doors, are wardrobes for passengers' outerwear. Usually, the crew's outfit is manufactured independently. The hooks hanging from the wardrobes' clothes are fastened

pipes. One row's width is 500–600 mm, and the hangers' pitch is 70–80 mm.

Conclusions

According to the analysis of choused prototypes, the long-range aircraft with a total seating capacity of up to 156 passengers was provided for in the design. The Airbus 319 was selected as the main prototype for the one, developed in this work, because it is a highest-selling airliner which periodically improving. This model attracts with enhanced efficiency, new engine option, the cabin with enhanced stowage compartment, sharklet blended winglets.

2. AIRCRAFT GEOMETRY CALCULATION

The arrangement of the aircraft's components and constructions, as well as all forms of loads (such as people, luggage, cargo, fuel, and so forth), comprise its layout.

The best conformance to the operational requirements guides the selection of the aircraft specifications and composition scheme.

2.1.1. Wing geometry calculation

1. Wing airfoil: Supercritical.
2. Relative thickness of the airfoil: 0.12
3. Location of the wing on fuselage: low-wing
4. Aspect ratio of the wing λ_w: 9.48
5. Taper ratio of the wing η_w: 4
6. Sweep back angle of a wing: 28 deg.
7. Wing area (S_{wing}):

$$S_{wing} = \frac{m_0 \cdot g}{P_0} = \frac{75\,500 \cdot 9.8}{5094} = 145.25\ \text{m}^2$$

Where m_o – take off mass of the aircraft, g – gravitational acceleration, P_o – wing loading at cruise regime of flight.

$$S_{wing} = \frac{m_0 \cdot g}{P_0} = \frac{75\,500 \cdot 9.8}{6139} = 120.5\ \text{m}^2$$

8. Wing span is:

$$l = \sqrt{S_{wing} \cdot \lambda_w} = \sqrt{120.5 \cdot 9.48} = 33.8\ \text{m}$$

9. Root chord is:

$$C_{root} = \frac{2 S_w \eta_w}{(1 + \eta_w) \cdot l} = 5.7\ \text{m}$$

10. Tip chord is:

$$C_{tip} = \frac{C_{root}}{\eta_w} = 1.425 \text{ m}$$

11. On board chord for trapezoidal shaped wing is:

$$C_{board} = C_{root} \cdot (1 - \frac{(\eta_w - 1) \cdot D_f}{\eta_w \cdot l_w}) = 5.7 \cdot (1 - \frac{(4-1) \cdot 3.9}{4 \cdot 33.8}) = 5.2 \text{ m}$$

12. Wing construction and spars position.

$x_{2spar} = 0.12 \cdot 1.425 = 0.171$

from the leading edge of current chord in the wing cross-section.

13. Mean aerodynamic chord definition.

The geometrical method of mean aerodynamic chord determination has been taken, which is presented at the fig.2.1.1.

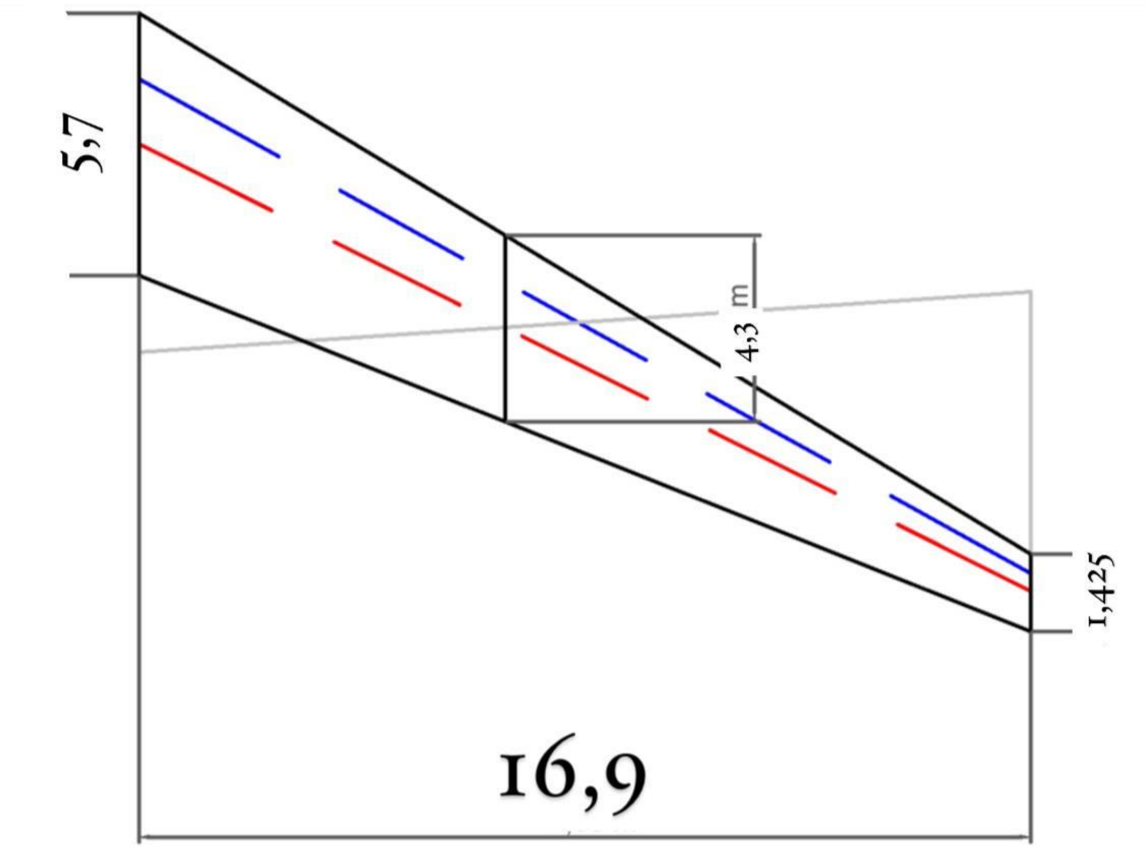

Fig. 2.1. Determination of mean aerodynamic chord.

Mean aerodynamic chord is equal $b_{MAC} = 4.53$ m.

Also, we could calculate the MAC by the approximately formulas:

For trapezoidal wing shape:

$$b_{MAC} = \frac{2}{3} \cdot \frac{C_{root}{}^2 + C_{root}C_{tip} + C_{tip}{}^2}{C_{root} + C_{tip}} = 3.99 \text{ m}$$

14. Ailerons design.

Ailerons geometrical parameters are determined in next consequence:

Ailerons span:

$$l_{aileron} = \frac{0.35 \cdot l_{wing}}{2} = \frac{0.35 \cdot 33.8}{2} = 5.9 \text{ m}$$

Ailerons chord:

$$C_{aileron} = 0.24 \cdot C_i = 0.24 \cdot 1.425 = 0.34\, m$$

Aileron area:

$$S_{aileron} = \frac{0.06 \cdot S_{wing}}{2} = \frac{0.06 \cdot 120.5}{2} = 3.6 \text{ m}^2$$

$$S_{in\ axial} = 0{,}31 \cdot S_{aileron} = 0{,}31 \cdot 3.6 = 1.116\, m^2$$

Area of aileron’s trim tabs:

For the aircraft with two engines:

$$S_{trim\ tabs} = 0.06 \cdot S_{aileron} = 0.06 \cdot 3.6 = 0.21 \text{ m}^2$$

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

So, the results are:

Ailerons span:

$$l_{aileron} = 0.35 \cdot \frac{l_w}{2} = 0.35 \cdot \frac{33.8}{2} = 5.9 \text{ m}$$

Aileron area:

$$S_{aileron} = 0.06 \cdot \frac{S_w}{2} = 0.06 \cdot \frac{120.5}{2} = 3.6 \text{ m}$$

Area of aileron’s trim tab for two engines airplane:

$$S_{trim\ tabs} = 0.06 \cdot S_{aileron} = 0.06 \cdot 3.6 = 0.21 \text{ m}^2$$

for single-slotted and double-slotted flaps:

$$C_f = 0.28 \cdot C_i = 0.28 \cdot 1.425 = 0.39 \text{ m}$$

for slats:

$C_s = 0.12 \cdot C_i = 0.12 \cdot 1.425 = 0.17$ m

It makes no sense to raise the suggested dosages of b and l of aileron. The span of mechanization reduces and the expansion of the aileron moment coefficient slows down as laileron increases above these values. The caisson's width reduces as baileron increases.

2.1.2 Fuselage layout

The aerodynamic requirements (streamlining and cross section) must be taken into consideration while determining the fuselage cross section's size and form.

Wave resistance has no bearing on subsonic passenger and cargo aircraft (V < 800 km/h). Therefore, we must select friction resistance Cxf and profile resistance Cxp from the list of values.

The value of wave resistance Cxw is influenced by the shape of the fuselage nose part during transonic and subsonic flights. Application of the fuselage nose part's round shape greatly reduces its wave resistance.

1. Length of the aircraft fuselage:

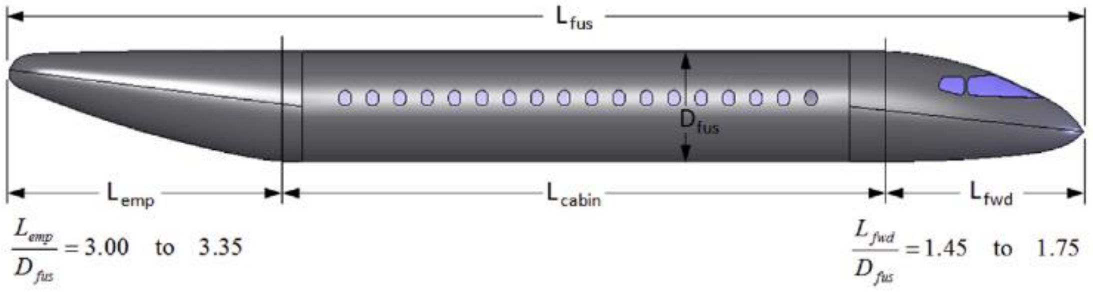

Fig. 2.2. Fuselage geometry

First of all, you need to find the length of the entire fuselage of the airplane:

$FR = L_{fus}/D_{fus}$, $\quad L_{fus} = FR_f \cdot D_{fus} = 8.57 \cdot 3.9 = 33.4$ m

FR – fineness ratio of the fuselage, D_{fus} – diameter of the fuselage.

2. Length of aircraft fuselage forward part:

$L_{fwd} = FR_{fp} \cdot D_{fus} = 1.7 \cdot 3.9 = 6.63$ m

3. Length of the fuselage tail part:

$L_{tail\,part} = FR_{tp} \cdot D_{fus} = 4.1 \cdot 3.9 = 16$ m

4. Cabin width:

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

Where 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), δ_{wall}= 80…120 – width of the wall (fuselage structure, insolation, decorative panels), mm.

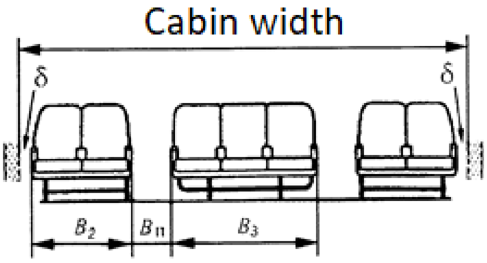

Fig. 2.3. Gaps between panels and armrests

Aisle width is defined in FAR 25.815.

$$B_{cab} = n_3 b_3 + n_{aisle} b_{aisle} + 2\delta + 2\delta_{wall} = 3700$$

5. Cabin height:

$H_{cab} = 1.48 + 0.17B_{cab} = 1.48 + 0.17 \cdot 3.7 = 2{,}1$ m

6. Length of the cabin:

$L_{cab} = L_1 + (N - 1) \cdot L_{seatpitch} + L_2 = 23.77$m

2.1.3 Baggage compartment:

$$S_{cargo} = \frac{M_{bag}}{0.4 \cdot K} + \frac{M_{cargo\&mail}}{0.6 \cdot K} = \frac{15 \cdot 156}{0.4 \cdot 500} + \frac{15 \cdot 156}{0.6 \cdot 500} = 19.5 \text{ m}^2$$

$V_{cargo} = v \cdot n_{pass} = 0.2 \cdot 156 = 31.2 \text{ m}^3$

2.1.4. Galleys and buffets:

$$V_{galley} = 0.1 \cdot n_{passenger} = 0.1 \cdot 156 = 15.6 \text{ m}^3$$

$$S_{galley} = \frac{V_{galley}}{H_{cab}} = \frac{15.6}{2.1} = 7.4 \text{ m}^2$$

2.1.5 Lavatories:

t> 4:00 one toilet for 40 passengers,

t = 2 ... 4 hours and 50 passengers

t <2 hours to 60 passengers.

- $t = \frac{Range_{flight}}{V_{cruise}} + 0.5 = \frac{6800}{828} + 0.5 = 8.7\ h$
- $N_{lavatory} = \frac{N_{passenger}}{40} = \frac{156}{40} < 4$

As a result, for my airplane I choose 4 toilets of the same design as the prototype, given their width of 1 meter and area: $S_{lav} = 1.5\text{m}^2$

2.1.6. Layout and calculation of basic parameters of tail unit

$$m_x^{Cy} = \bar{x}_{cg} - \bar{x}_F < 0$$

S_{HTU}=(0.18..0.25) $\cdot$ S = (21.69..30.125);

S_{VTU}=(0.12..0.20) $\cdot$ S = (14.46..24.1);

$$S_{HTU} = \frac{b_{mac} \cdot S}{L_{htu}} \cdot A_{HTU} = \frac{3.99 \cdot 120.5}{19.26} \cdot 0.8 = 19.97 \text{ m}^2$$

$$S_{VTU} = \frac{l \cdot S}{L_{vtu}} \cdot A_{VTU} = \frac{33.8 \cdot 120.5}{17.42} \cdot 0.08 = 18 \text{ m}^2$$

$$L_{VTU} = 2.1 \cdot b_{mac} = 2.1 \cdot 3.99 = 8.3 \text{ m}$$

$$L_{VTU} = 2.2 \cdot \text{b}_{mac} = 2.2 \cdot 3.99 = 8.7 \text{ m}$$

$$S_{el} = 0.35 \cdot S_{HTU} = 0.35 \cdot 19.97 = 6.98 \text{ m}^2$$

$$S_{rudder} = 0.21 \cdot S_{VTU} = 0.21 \cdot 18 = 3.78 \text{ m}^2$$

$S_{able} \approx S_{rudder} = 3.78\ \mathrm{m}^2$

$\mathrm{S_{tabs}} = 0.12 \cdot S_{rudder} = 0.12 \cdot 3.78 = 0.45\ \mathrm{m}^2$

$l_{HTU} = 0.4 \cdot l_{wing} = 0.4 \cdot 33.8 = 13.52\ \mathrm{m}$

$h_{VTU} = (0.14..0.2) \cdot l_{wing} = 0.18 \cdot 33.8 = 6.08\ \mathrm{m}^2$

$\eta_{htu} = 2.4 \qquad \eta_{vtu} = 1.3$

$\lambda_{htu} = 1.9 \qquad \lambda_{vtu} = 4.74$

$$b_{tip} = \frac{2S_{htu}}{(\eta_{htu}+1)l_{htu}} = \frac{2 \cdot 19.97}{(2.4+1) \cdot 13.52} = 0.9\ m$$

$$b_{mac} = 0.66 \cdot \frac{{\eta_{htu}}^2 + \eta_{htu} + 1}{\eta_{htu}+1} \cdot b_{tip} = 0.66 \cdot \frac{2.4^2 + 2.4 + 1}{2.4+1} \cdot 0.9 = 1.6\ m$$

$b_{root} = b_{tip} \cdot \eta_{htu} = 0.9 \cdot 2.4 = 2.16\ m$

$$b_{tip} = \frac{2S_{vtu}}{(\eta_{vtu}+1)h_{vtu}} = \frac{2 \cdot 18}{(1.3+1) \cdot 6.08} = 2.57\ m$$

$$b_{mac} = 0.66 \cdot \frac{{\eta_{vtu}}^2 + \eta_{vtu} + 1}{\eta_{vtu}+1} \cdot b_{tip} = 0.66 \cdot \frac{1.3^2 + 1.3 + 1}{1.3+1} \cdot 2.57 = 2.94\ m$$

$b_{root} = b_{tip} \cdot \eta_{vtu} = 2.57 \cdot 1.3 = 3.3\ m$

2.1.7. Calculation of basic parameters and layout of landing gear

$\mathrm{Bm} = (0.15..0.20) \cdot b_{MAC} = 0.17 \cdot 3.99 = 0.67\ \mathrm{m}$

$\mathrm{B} = (0.3..0.4) \cdot l_f = (6..10) \cdot \mathrm{Bm} = 0.35 \cdot 33.4 = 11.69\ \mathrm{m}$

$\mathrm{Bn} = \mathrm{B} - \mathrm{Bm} = 11.69 - 0.67 = 11.02\ \mathrm{m}$

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

$\mathrm{T} = 0.8 \cdot 11.69 = 9.3\ \mathrm{m}$

$$F_{main} = \frac{(B - B_m) \cdot m_0 \cdot 9.81}{B \cdot n \cdot z} = \frac{11.02 \cdot 75500 \cdot 9.81}{11.69 \cdot 3 \cdot 2} = 116\,367.52 \text{ kg}$$

$$F_{nose} = \frac{B_m \cdot m_0 \cdot 9.81 \cdot K_g}{B \cdot z} = \frac{0.67 \cdot 75500 \cdot 9.81 \cdot 1.7}{11.69 \cdot 2} = 36\,082.38 \text{ kg}$$

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

K_g = 1.5..2.0 – dynamics coefficient.

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

$$F_{main} = 116\,367.52 \; kg = 256546.6 \text{ lbs}$$

$$F_{nose} = 36\,082.38 \; kg = 79548.096 \text{ lbs}$$

$$V_{rated} = 290.66 \; km/h = 180.6 \text{ mph}$$

$$F_{main} = \frac{(B - B_m) \cdot m_0 \cdot 9.81}{B \cdot n \cdot z} = \frac{11.02 \cdot 75500 \cdot 9.81}{11.69 \cdot 6 \cdot 4} = 29091 \text{ kg}$$

$$F_{nose} = \frac{B_m \cdot m_0 \cdot 9.81 \cdot K_g}{B \cdot z} = \frac{0.67 \cdot 75500 \cdot 9.81 \cdot 1.7}{11.69 \cdot 4} = 18041 \text{ kg}$$

$$F_{main} = 29091 \; kg = 64134.7 \text{ lbs}$$

$$F_{nose} = 18041 \; kg = 39773.6 \text{ lbs}$$

2.2.1. Determination of centers of gravity of masses of the equipped wing

$$X_w{}' = \frac{\sum m_i{}' x_i{}'}{\sum m_i{}'}$$

Table 2.2.1. - Trim sheet of equipped wing masses

N	Object name	Mass		C.G coordinates Xi, м	Moment of mass
		units	total mass m(i)		
1	wing	0.1063 4	8028,67	1,94	15575,6
2	fuel system	0.0099	747,45	1,94	1450
3	Flight control system, 30%	0.0018	135,9	2,71	368,29
4	electrical equipment, 10%	0.0032	241,66	0,45	108,74
5	anti-ice system , 50%	0.003	226,5	0,45	101,92
6	hydraulic systems , 70%	0.0115 5	872	2,71	2363,12
7	Engines (-fuel system)	0.087	6568,5	5.44	35729,92
	equipped wing without landing gear and fuel	0,2227 9	16820,68	15,67	263580,0 5
8	nose landing gear (20%)	0.0073 4	554,17	23,066	12782,48
9	main landing gear (80%)	0.029	2189,5	4,704	10299,4
1	fuel	0.3342 8	25238,14	1,94	48961,99
	Total	0,5934	44802,49	11,345	335623,9

Table 2.2.1. - Trim sheet of equipped fuselage masses

N	Objects names	Mass		C.G coordinates Xi, м	Moment of mass
		units	total mass		
1	fuselage	0.06798	5132,49	16,7	85712.58
2	horizontal tail	0.00863	651,56	13,52	8809,09
3	vertical tail	0.00852	642,26	8,3	5330,75
4	navigation equipment	0.0047	354,85	2	709,7
5	radio equipment	0.0023	173,65	1	173,65
6	radar	0.0031	234,05	0.5	117,02
7	instrument panel	0.0054	407,7	2.5	1019,25
8	Flight control system 70%	0.089	6719,5	16,7	112215,65
9	hydraulic system 30%	0.0049	369,95	23,38	8649,431
1	anti ice system, 20%	0.004	302	26,72	8069,44
	air-conditioning system, 40%	0.0087	656,85	16,7	10969,39
1	electrical equipment, 90%	0.0289	2181,95	16,7	36438,56
1	Load devices equipment	0.01566	1182,36	3,3	49012,78
1	Not typical equipment	0.0033	249,15	20	4983
1	Additional equipment (emergency equipment)	0.00331	249,9	18	4498,2
1	Operational items	0.02165	1635,575	25	40889,37
1	Furnishing	0.0121	913,55	26,48	24190,8
	Passenger equipment:	0.0153	1155,15	34	39275,1
	1	2	3	4	5

The end of the table 2.2.1.

1	2	3	4	5
equipped fuselage without payload	0,469025	36882,5	15.08	556188
payload	0.19672	14852,36	26	386161,36
TOTAL	0,665745	38064,855	20,54	

2.2.2 Determination of the centre of gravity of the equipped fuselage

$$X_f{}^{/} = \frac{\sum m_i{}^{/} X_i{}^{/}}{\sum m_i{}^{/}}$$

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

$$X_{MAC} = \frac{m_f x_f + m_w \cdot x_w{}^{/} - m_0 C}{m_0 - m_w}$$

where m_0 – aircraft takeoff mass, kg;

m_f – mass of fully equipped fuselage, kg;

X_f – coordination of fully equipped fuselage,

m_w – mass of fully equipped wing, kg;

X_w – coordination of equipped wing

C – distance from MAC leading edge to the C.G. point, determined by the designer.

C = (0,22...0,25) B_{MAC} – low wing ;

C = (0,23...0,32) B_{MAC} – high wing;

For sweptback wings;

at X = 30°...40°

C = (0,28...0,32) B_{MAC}

at X= 45°

C = (0,32...0,36) B_{MAC}

$$\overline{X_T} = \overline{X_C} = \frac{X_{C.G.} - X_{MAC}}{b_{MAA}} \cdot 100\% = \frac{C}{b_{MAA}} \cdot 100\%$$

2.2.3. Calculation of C.G. positioning variants

Table 2.2.3 - Calculation of the C.G. positioning variants

Name	Mass, Kg	Coordinate	Mass moment
object	m_i	C.G., M	Kg.m
equipped wing (without fuel and landing gear)	8028,67	1,94	15575,6
Nose landing gear (extended)	554,17	23,066	12782,48
main landing gear (extended)	2189,5	4,704	10299,4
fuel/fuel reserve	25238,14	1,94	48961,99
equipped fuselage (without payload)	36882,5	15.08	556188
passengers of economy class	1155,15	34	39275,1
nose landing gear (retracted)	554,17	23,066	12782,48
main landing gear (retracted)	2189,5	4,704	10299,4

Table 2.2.3. - Airplanes C.G. position variants

№	Variants of the loading	Mass, kg	Moment of the mass, kg*m	Center of mass, m	Centering
1	take off mass (L.G. extended)	82867	1093240	14,48	0.1999
	take off mass (L.G. retracted)	82867	1087200	14,4	0.1798
	landing weight (LG extended)	69 867	937500	15	0.3302
	ferry version	57 563	868050	15,08	0.3503
	parking version	32 324,8	506529,61	15,67	0.498188

Conclusion

I have the following outcomes from this designing work:

-calculating the airplane's center of gravity;

-calculating the landing gear's primary geometrical parameters;

-selecting wheels that meet the necessary specifications;

-designing the nose landing gear.

By placing the two engines in the back of the fuselage, the aircraft's design allows for increased wing aerodynamic characteristics, decreased engine jet stream aerodynamic effects, and lower passenger cabin noise levels.

-a sensible arrangement with handy service areas;

-an ergonomic layout that maximizes both shared and private space;

-a contemporary interior design;

-minimal noise;

3. TYPES, METHODS AND DEVELOPMENT OF RIVETED JOINTS OF AIRCRAFT SKIN

3.1.1 Types of joints used in aircraft skin

Joints in aviation

There are two main types of connecting parts made of thin sheet metal – riveted and welding joints. They used in very different parts and structures of the aircraft, like engines, structural elements, control surfaces, etc. Although there are only two types of joints used in aviation, there are many types that are also widely used in aviation.

Welding joints

Welding joint is a point where two or more metal units connecting in one single unit, by using heating and/or plastic deformation by special techniques and geometry. It is necessary for it`s formation fulfillment of the following conditions: freeing of welding surfaces from contamination, oxides and foreign atoms adsorbed on them; energy activation of surface atoms, which facilitates their interaction with each other, convergence of welding surfaces at a distance comparable to the interatomic distance in the welded workpieces. There five main welding joints: Butt Joint, Tee Joint, Corner Joint, Lap Joint, and Edge Joint (Fig 3.1.1.)

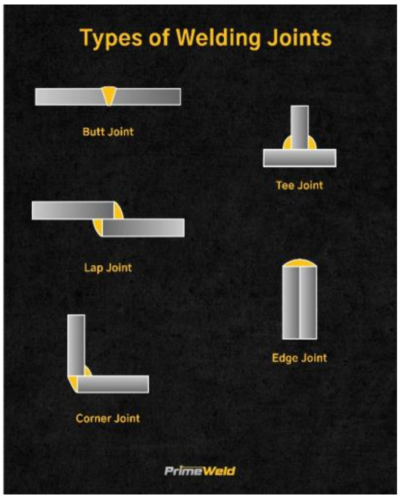

Figure 3.1.1 Types of welding joints

Riveting joints

Rivets are used to create a so-called "inseparable" connection. Usually, rivets are used to connect thin metal sheets, as well as fairly heavy constructions.

Rivets differ structurally, by the method of fastening, and by the material of manufacture.

Types of rivets:

1. Hammer rivets are the oldest and simplest

a type of rivet, but despite this, is widely used to this day. They come in different sizes, are made of different materials (copper, brass, aluminum, steel) and have different shapes.

2. Tubular, semi-tubular and piston rivets. These types of rivets

are used in connections with a small mechanical load, because they are hollow in the middle and not very strong. These rivets are used to fasten soft materials (plastic, leather, fabrics).

3. Set rivets. This type of rivets is tubular rivets (hollow), inside of which there is a punch, which is used to form the locking head from the second sides (no need to access the two ends of the rivet). These rivets are used only in rigid thick-walled structures.

4. Threaded rivets. This type of rivet has a thread on the inner surface, which is used when fastening the rivet to the material.

A special tool is required to install this type of rivet

riveting tool. Threaded rivets are more often used in everyday life.

The riveted connection is widely used in aircraft construction.

The cladding of modern aircraft is made of individual sheets of duralumin

alloys Sheets are attached to the aircraft frame with rivets (more often with

same material).

There are also two main forms of the rivets:

Rivet with a convex head - a semicircular head protrudes above the surface of the material;

Rivet with hidden head - the head is hidden, does not protrude beyond the surface of the material.

3.1.2 Riveting joints, and why they uses in aircraft assembly

Rivered joint is a simple and effective way to connect two components together. There are different types of riveting joints, including lap joints and butt joints. However, they are all used to permanently join two components together, there is two main subtypes of rivets using in aircraft skin construction:

Solid Rivets: Solid rivets are one of the most traditional types of rivets used in aircraft construction. They are typically made of aluminum and are installed by heating the shank and forming a head on the opposite side. Solid rivets provide strong, permanent joints.

Blind Rivets: Blind rivets, also known as pop rivets, are used in areas where only one side of the joint is accessible for installation. They are inserted into pre-drilled holes and mechanically deformed to create a second head on the blind side.

So why rivet joints are more popular, then welding jonts in skin structure, there is some main reasons:

Aluminum Isn’t Tolerant of Heat

Another issue people construct airplanes with riveted joints in place of any welded joints is due to the fact that the aluminum materials used in constructing the main body of the airplane are not resistant to heat and this makes it difficult to weld the joints. Aluminum is commonly used for the fabrication of commercial aircraft due to the following reasons Most commercial aircraft have a metal body which mainly comprised of aluminum. First of all, aluminum is cheap and easily obtainable. Not to mention the fact that aluminum is also a lightweight material. Aluminum also makes it possible to build aircraft bodies using lighter materials as compared to other metals, with concomitant benefits in energy efficiency. Aluminum though is susceptible to heat and hence when heated such as through welding, it becomes weaker, most aerospace manufacturing companies thus opt to connect the joints by using rivets.

Riveted Joints Are Stronger

The greatest advantage of riveted joints in an aircraft is that more than welded joints, it is stronger and also it has a longer tested life cycle. During welding, two components are connected from the outside, and this makes their connection independent of size. However, employing a rivet connects the two parts from the interior, and thus one can be assured of a tightly joined surface, which tends to be strong and durable. This is especially significant with aircrafts as flying at a speed of 550 miles per hour and 30000 feet above ground level put a lot of stress on the joints of the aircraft.

Riveted Joints Are Easier to Inspect

Riveted joints also have an additional advantage of ease of inspection compared to welded joints. In the case of riveted joint, for instance, checking for the tightness of the rivet simply involves a casual visual assessment to confirm that the two pieces that are joined together by the rivet are securely fastened. In this case, when a welded joint is made on two pieces of metal, a machine or a device has to be used in order to apply pressure on the joined parts. In essence, visual inspection is as complicated and challenges as it is to attempt a welding job on a piece of steel. Therefore, aerospace manufacturing firm utilize riveted joints because they facilitate both the assembling and the servicing of the airplanes.

Even with riveted joints, some of today’s commercial aircraft possess a few welded parts. For the important part of the aircraft body, however, rivets are used because of their ability to remain strong even under great pressure that tends to cause breaking or some other forms of damage. It has been cited as a safer and effective means through which aerospace manufacturing firms can construct aircrafts.However, rivets also have some disadvantages, compared to welding joints. Riveted joints is a time-consuming process. Time is also a very important parameter in aircraft designing, it can be way faster to construct an aircraft, using only welding joints. Also riveted joints required more maintenance over the time, and changing a rivets periodicaly can slowly destroy a skin structure, in particularly at the places of joints of materials.

3.1.3 The structure of the fuselage and the purpose of its elements

Skin

It`s a shell, This is a shell that forms the outer surface of the fuselage, wings and the tail assembly of the aircraft, and serves to give them an aerodynamic shape.

The aerodynamic characteristics of an aircraft airframe depend on the quality of the skin surface. In modern aircraft construction, rigid is most often used metal cladding, as it best meets the requirements of aerodynamics, strength, stiffness and mass. It simultaneously perceives external aerodynamic loads, bending and torque moments, as well as shear forces acting on the frame of the aircraft. Materials for the manufacture of hard cladding are: aluminum, titanium and metal alloys, composite materials, aviation plywood. Steel and titanium are used in the construction of supersonic aircraft.

The fuselage skin material is selected depending on the load.

The upper zone of the fuselage skin receives tensile forces over the entire area sheathing and stringers, and the lower zone — compressive loads only part of the skin attached to the stringers. In a hermetic case the thickness of the cladding is selected taking into account the internal excess pressure. There are three possible ways to connect the skin to the frame:

• the cladding is attached only to the stringers,

• the cladding is attached to both stringers and frames,

• the cladding is attached only to the frames.

In the first case, only longitudinal rivet seams are formed, and there are no transverse seams, which improves the aerodynamics of the fuselage. Unfixed on in frames, the cladding loses its stability at lower loads, which leads to an increase in the mass of the structure. To avoid this often sheathing connected to the frame with an additional overlay — a compensator. Third the fastening method is used only in sheathing (stringless, honeycomb) fuselages.

Stringers

Stringer is a longitudinal element of the power set of an aircraft, associated with the skin and ribs of the wing or fuselage frames.

It is intended for the perception of axial tensile and compressive forces. He perceives as well as local aerodynamic loads, reinforces the cladding, increasing its hardness. Depending on the purpose and location, there are stringers local strengthening (at the places of action of concentrated loads or at the edges cutouts in the cladding), typical (ensure rigidity of the structure), joint (on cladding joints), front and end. In the designs of modern aircraft stringers from pressed and bent profiles are installed with a step of 150...400 mm To increase the durability of the structure in places where cracks may appear in stringers made of high-strength materials are placed on the skin, which perform the role crack propagation limiters ("stoppers").

The functions are determined by the structural and power scheme. In the spar wing stringers are used to reinforce the skin in order to raise it critical tangential stresses during operation of the wing for torsion and bending are taken participation together with the cladding in the transfer of aerodynamic load to ribs, working on the transverse bend. In the monoblock wing, in addition, the stringer set, together with the cladding, absorbs most of the bending moment At the same time, stringers and cladding work in compression or tension normal stresses are applied. The weight of stringers is, depending on design, from 3 to 12 percent of the weight of the entire wing.

There are pressed and bent stringers, open and closed section.

Pressed profiles have higher critical compressive stresses than bent ones

profiles of similar sections and equal cross-sectional area. Therefore, in compressed panels
monoblock wings, as a rule, stringers from pressed profiles are used.
Bent profiles are sometimes used for stringers, which under the main load, acting on the wing, work on tension. Closed profiles, forming together with a closed circuit with a skin, ensure obtaining higher critical stresses than profiles of other types equal in cross-sectional area. To decrease mass and creating a structure of the same strength, stringers are made with a variable for
span with a cross-sectional area that decreases towards the ends of the wing.
The thickness of the walls of the stringers usually ranges from 0.5 to 3.0 mm.

Frame

The frame is a metal transverse element of the power set of the hull aircraft, which ensures the rigidity of the skin and preserves its shape.
On aircraft, the frame is the main transverse element fuselage power set. It ensures the shape and rigidity of the section and transmits local concentrated loads on the cladding or other power elements.
It is usually installed perpendicular to the axis of the aircraft unit or at the angle of action of the concentrated load and, as a rule, has the form, the appropriate form of cladding.
Frames are divided into two main groups: typical (normal) and power (reinforced). In addition, joint frames are used: double frames in unit connectors. Frames installed only on part of the length contour of the shell, are called half-frames.
Typical frames serve only to provide the shape of the fuselage.
They are made in the form of a rim bent from a metal sheet, the shape of which corresponds cladding contour. They are divided into reinforcing (the cladding is attached only

to the stringer), distribution (the cladding is attached to the frame and stringer).
Power frames are used to transfer concentrated loads.
They are divided into wall (solid), shaped, frame, in the form of a horseshoe
beams etc. They are installed along the edges of the cutouts in the paneling (under doors, hatches, etc.),
in the places where the wing, chassis, power plant, feathering are attached, on the ends cargo compartments.

3.1.4 Properties and description of materials used in aircraft skin

Aluminium alloys are desirable in that they are light and stable such that the majority of today's military and civilian aircraft utilize aluminum alloy in the manufacture of aircraft skins.

2000 series aluminum alloys, mainly consists of Cu, which has better strength, heat resistance, and processing performance, and can have good strength and process performance at high temperature, which can be used in aerospace high temperature resistance parts.

2024 aluminum is typical hard aluminum alloy, comsisting of aluminum, copper, magnesium. Its composition is optimal and its general workability is quite satisfactory. Subsequently, 2024 aluminum alloy after heat treatment is treated by solid solution treatment to get relatively high compressive strength and ductility. Owing to its high tensile strength, this type of fabric is mainly used in manufacturing skins, beams, bulkheads, and wings.

7000 series aluminum alloys elements are mainly Zn elements. The aluminum alloy comes under heat treatment so that the toughness of the particular material is enhanced. It is pointed out that the addition of Mg element can enhance the capacity of hot deformation and the range of quenching. Aluminium 7000 series alloys are strong weldable alloys characterized by high stress corrosion behaviour.

7050 aluminum is characterized by high strength, stressing resistance of cracking, and ultimate toughness. It possesses comparatively low quench sensitivity with less strength retention at the thicker sections, thus ideally for thick plate productions (thick plates range from 3 to 6 inches). thermore, 7050 aluminum alloy sheet is the best choise for fuselage frame, bulkhead as well as wing skin.

Titanium alloys used particularly for supersonic and hypersonic aircrafts. They possess a high tensile strength, strength at elevated temperatures and high strength-to-weight ratios, They also exhibit high stiffness and can also resist high temperatures and pressures. They also have improved resistance to corrosion and fatigue and they help to reduce the weight of the structures enabling easier transportation of commodities. Nonetheless, titanium alloys are very heavy, expensive, and rare resources in serial production processing. They also have low ductility and this makes it difficult to bend or format them, and when it comes to joining these metals it is also a herculean task. Hence, titanium alloys are applied in the wing construction sparingly, most if not all, in the leading edge, the spar, or the skin.

Composite materials thus refer to structures that are made of at least two different materials that can be combined to produce a new material with superior characteristics. For instance, one type of composite material carbon fiber reinforced polymer (CFRP) is made of carbon fiber and polymer matrix. CFRP is used mostly for aerospace application, sports, and automotive and has high strength and stiffness, is light, and it has high fatigue, corrosion, and temperature resistance. It is arguably used majorly in aircraft wings especially in airplanes with high performances as well as stealth capabilities. However, the use of composite materials can also be very expensive, involve high degree of material and design sophistication, and present significant difficulties in manufacturing, testing and repair. These they also need special care and handling since they are inclined to lose their quality or get affected in the process.

3.1.5. Damage of the aircraft skin, it`s types and formation factors

Aircraft damage is a disruptive event that involves change aircraft element from airworthiness to partial airworthiness suitability, and in the extreme case - non-volatility. This condition occurs due to exceeding permissible limits. Damage to the aircraft can occur both in the whole object and in its separate elements and units. Such thus, the damage leads to the repair or replacement of the element or block for the flight period. Identification of the causes of damage plays an important role in maintaining a high level of reliability of aircraft operation. Appearance damage depends on factors inside the object, the environment environment, operating technologies and service personnel. Importantly to determine when the damage occurred, in what period of use of the aircraft.

Damage to an aircraft's skin, which forms the outer covering of the fuselage, wings, and other structural components, can occur due to various factors. Here are common types of damage to aircraft skin and their formation factors:

Scratches and Abrasions:

Scratches and abrasions can occur during ground handling, maintenance procedures, or when the aircraft is exposed to debris or foreign objects during taxiing, takeoff, or landing. Factors such as rough surfaces, improper handling equipment, or contact with abrasive materials can contribute to scratches and abrasions.

Dents:

Dents can result from impacts with ground service equipment, runway debris, or hail during flight. Additionally, bird strikes or collisions with other airborne objects can cause dents on the aircraft's skin. Factors such as operating in congested airport environments or flying through turbulent weather conditions increase the risk of encountering objects that can cause dents.

Corrosion:

Corrosion occurs when the aircraft's skin is exposed to moisture, oxygen, and other corrosive agents over time. Factors such as exposure to saltwater, acidic rain, industrial pollutants, or high humidity levels can accelerate corrosion processes. Improper maintenance practices, such as inadequate corrosion protection treatments or prolonged exposure to environmental contaminants, can also contribute to corrosion.

Cracks:

Cracks in the aircraft's skin can develop due to various factors, including fatigue, stress, manufacturing defects, or improper maintenance practices. Factors such as cyclic loading, thermal expansion and contraction, structural vibrations, and material imperfections can lead to crack initiation and propagation. Additionally, exposure to extreme environmental conditions, such as temperature fluctuations or pressurization cycles, can contribute to crack formation.

Delamination:

Delamination occurs when layers of composite materials in the aircraft's skin separate or peel apart. Factors such as manufacturing defects, impact damage, moisture ingress, or exposure to high temperatures can weaken the adhesive bonds between composite layers, leading to delamination. Improper storage conditions, maintenance procedures, or prolonged exposure to ultraviolet (UV) radiation can also accelerate delamination processes in composite materials.

3.2. CAD systems designing

3.2.1 CAD systems

AutoCad

AutoCAD (Automated Computer Aided Drafting and Design) is a CAD system designed to preparing technical documentation and building drawings of any difficulty. AutoCAD created by company “Autodesk”, which is a global leader in software for designers, engineers, builders, and creators. Autocad allows to use primitive shapes to get more complex objects. Additionally, this software provides a wide opportunities for working with layers and annotation objects, including sizes, texts, and designations. A wide spectrum of tools for complex three-dimensional modeling, including solid, surface, and polygonal modeling, is provided by AutoCAD. With a rendering system, AutoCAD enables you to get high quality models with excellent details. However, it should be noted that the lack of three-dimensional parameterization does not allow AutoCAD to directly compete with middle-class CAD, such as Inventor, SolidWorks, and others. Also, AutoCAD allows you to parameterize any drawing, which is very useful when various and frequent changes in the drawing are needed. Parameterization allows you to set certain conditions and values to points and geometric objects, for this you only need to change the numerical values, and the drawing will be automatically rebuilt according to the pre-defined parameters. AutoCAD also synergizes well with other systems, allowing you to view and open drawings in any system and make changes that are more convenient, accessible, and sometimes even exclusive to certain systems.

SolidWorks

In modeling SolidWorks uses a special technique where by the program is driven by specific key characteristics (parameters) of the model. These can be widths, heights, depths, orientations or arrangements of one particular part of the model to another part of the model.

Creating a model in SolidWorks typically begins with a 2D sketch consisting of the elements like points, lines, arcs, conics (excluding hyperbolas), and splines. Dimensions are incorporated into the sketch to specify the dimensions and positions of these elements. Relations are employed to establish characteristics such as tangents, parallels, perpendiculars, and concentricities. SolidWorks operates in a parametric manner, where dimensions and relationships dictate the geometry, not the other way around. The dimensions within the sketch can be controlled either autonomously or through connections to other parameters within or beyond the sketch.

CATIA

CATIA (Computer Aided Three-dimensional Interactive Application) computer-aided design (CAD) system developed by the French company Dassault Systèms. It encompasses CAD, computer-aided manufacturing (CAM), and engineering analysis (CAE), offering advanced 3D modeling tools along with 26 software subsystems for simulating complex technological processes and analyzing data. The system is equipped with a unified database containing both textual and graphic information. CATIA is adept at addressing a wide range of technical tasks related to production preparation, from initial conceptual design to the generation of drawings, specifications, assembly diagrams, and control programs for numerically controlled machines. Its software portfolio caters to the requirements of seven major industries including aerospace, automotive, shipbuilding, mechanical engineering, electronics, plant construction, and general consumer goods. With over 300 functional modules, CATIA's products can be categorized and grouped based on platforms, domains of applicability, configurations, and individual products. Platforms represent subsets of products tailored to address developers' tasks at varying levels of functionality, productivity, and corresponding cost levels.

3.2.2 Modeling part of the aircraft skin in CAD system

Before developing the model of the skin and in its details, it`s nessessary to analyze its construction.

The skin of the aircraft is fastened with riveted joints to the frame of the aircraft. As already mentioned, stringers pass through the frames, thereby forming the framework of the aircraft and a place for attaching the skin. Through special, pre-prepared holes, cladding plates are riveted to this structure, the elements of which depend on the place of attachment and the aircraft itself.

3D model of aircraft skin construction

Let's develop a 3D model, the part is modeled in the form of a 500x400x3 plate

To create a plane, you need to select an axis and select it as a sketch plane. Once the plane is selected, we can apply 2D features to it, which we can later turn into 3D feature extrusion objects. To create our plate, you need to draw a 500x500 rectangle, specifying the coordinates of the first point and the second. When the plate is ready, we select it and pull it up by 3 millimeters. This is how we get a 500x500x3 plate.

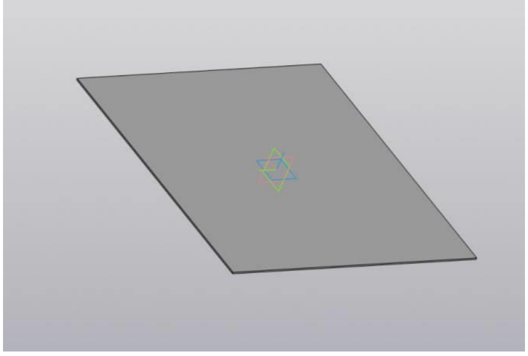

Fig. 3.2.1 500x500x3 plate model

After that, we put holes for rivets with a diameter of 5 mm on our plate, for this we take its upper face as a sketch, the difference between a rivet hole with a semicircular head and a hidden head is that for the second one is added countersinks on the holes.

The holes themselves are placed evenly along the perimeter of the plate with the same interval, which will be about 50 mm, along the x and y axes. For my plate I chose round head rivets so no additional countersinks holes were needed. We measure the indents from the edges, and put a circle with a diameter of 5 mm, then press the button to copy the element, copy it along the perimeter with a one-point interval of 50 mm. After that, we cut them out. Thus, our plate is ready.

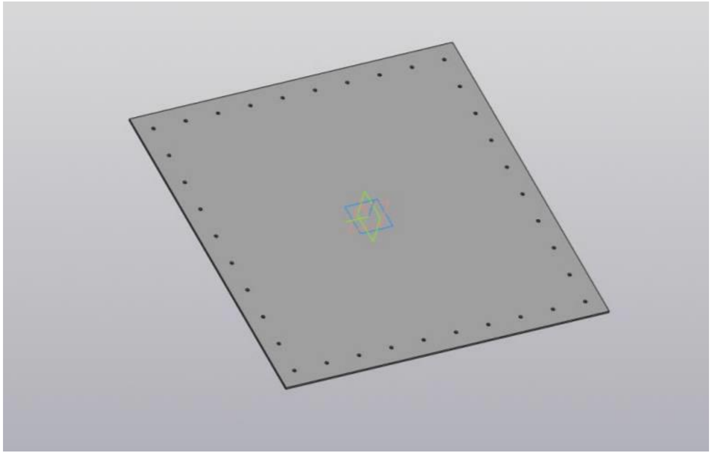

Fig. 3.2.2 Plate with the holes model

I chose rivets with a semicircular head, the model will be created based on a photo from free access.

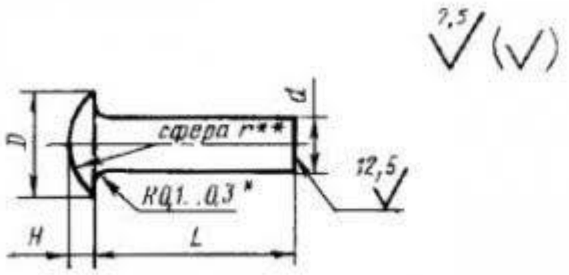

Figure 3.2.3 Requirements for rivets with a semicircular head

To build them, you need to make a cylinder with a height of 8 mm, and on top of it a semisphere with a diameter of 6 mm, by the method of rotation along the axis of a semicircle.

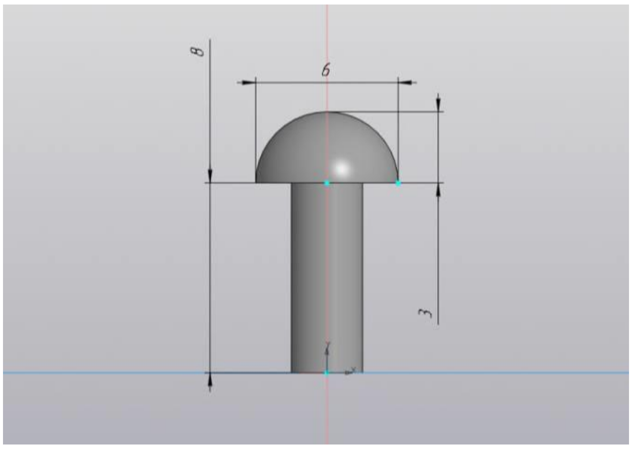

Fig. 3.2.4 Rivet model with dimensions

Stringers will be used to fasten the plate along the longitudinal axis, while frames will be used for the transverse one. Stringers and frames will be built according to cross-sections found in free access.

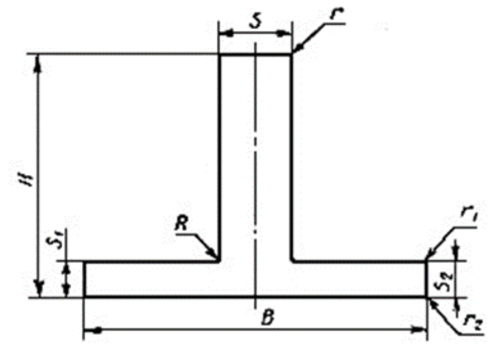

Fig. 3.2.5 Crossection of stringer

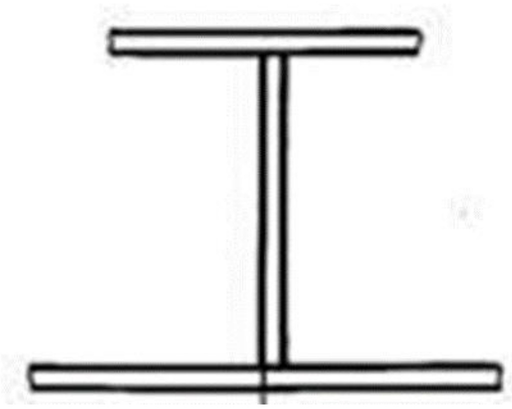

Fig. 3.2.6 Frame crossection

For the stringer, I first built a 500x50 rectangle and pullit up by the z-axis by 3mm. After that, we make a rectangular prism 22x3.5x500 in the center of the resulting figure. resulting in our stringer.

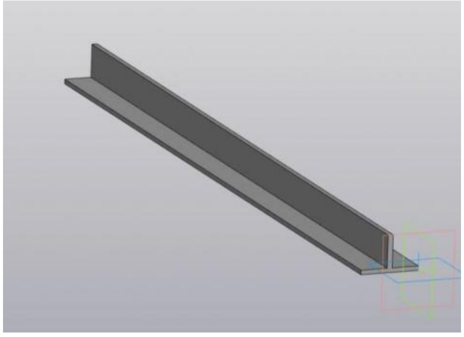

Fig. 3.2.7 Stringer model

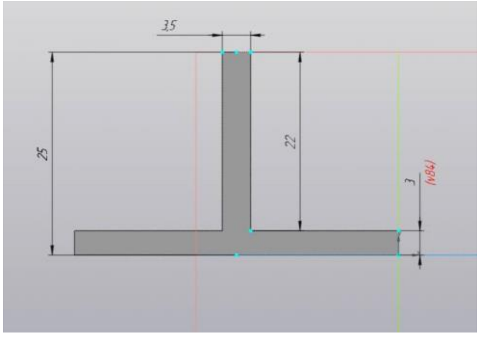

Fig. 3.2.8 Stringer crossection with dimentions

We make the frame in the same way, but we add another surface on top, which will be a mirror of the lower one. The upper and lower surfaces will be 500x50x3, and the bridge between them will be 500x46x10.

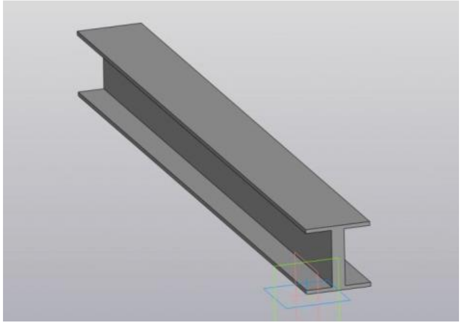

Fig. 3.2.9 Frame model

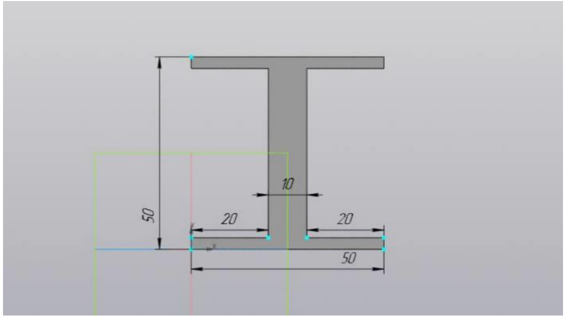

Fig. 3.2.10 Frame crossection with dimentions

Now let's create an assembly file and load all our parts into it, as we need to connect after that. In each hole in the plate, we add the rivet we drew, and on the other side we attach the frame. Than we pass and attach our stringer through the frame.

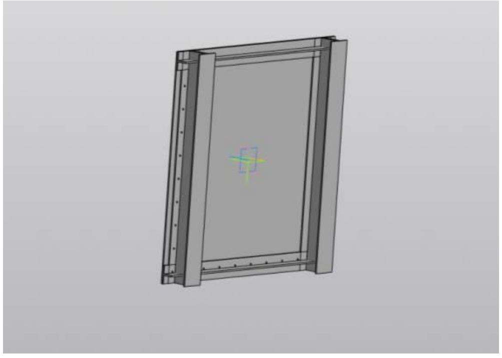

Fig. 3.2.11 Aircraft skin assembly model (a)

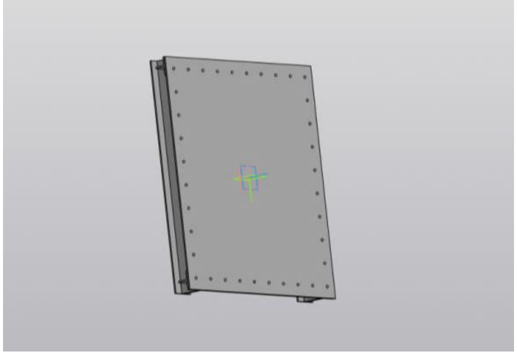

Fig. 3.2.12 Aircraft skin assembly model (b)

CONCLUSION

In most cases, riveted joints are used in the skin of the aircraft. Although welding seams, their variability and types have their advantages, rivets still win in terms of the number and importance of advantages. However, welding is suitable for the connections of frame elements and various systems, where it will be not only problematic, but also not advisable to put rivets. Such advantages as

Weight: Riveting is usually lighter than welding, which is important in aircraft construction where every gram of weight counts. Lighter equipment and materials make it possible to reduce the weight of the aircraft, which increases its flight characteristics and efficiency.

Efficiency: Rivets provide effective load distribution because they are distributed over the entire surface of the joint, while welding can create concentrated load points that can lead to damage or material fatigue over time.

Availability and Repairability: Rivets can be easily replaced and repaired when needed, allowing for faster aircraft maintenance. Welding, on the other hand, can require complex procedures and equipment to repair.

Materials: Rivets can be used to join different materials such as aluminum, titanium, composite materials, etc. Welding can be difficult when joining materials with different properties, such as temperature resistance or coefficient of thermal expansion.

GENERAL CONCLUSIONS

1. In this project, was completed a work with developing a long-range passenger aircraft with a passenger capacity of up to 156 passengers. It was determined the geometric parameters and centering of the A319 aircraft, based on the main geometrical characteristics, operational purpose and number of passengers.

2. The centrering of the projected aircraft were carried out, the layout of the projected aircraft was analysed and justified in accordance with the issued technical task, and drawings were made on the basis of the A319 prototype.

3. Analysing the types of thin sheet metal joints, identifying the advantages and disadvantages of each. Consideration of CAD systems and development of a model of the connection between the skin part and the aircraft frame. Work was done to compare the connections with the conditions of the materials used in the ski

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3. Основи авіації (вступ до спеціальності): підручник / С. Р. Ігнатович, О. В. Попов, В. О. Максимов та ін.// - К.: НАУ, 2023. – 296 с.

Appendix

Appendix A

Performed by: Heilenko Volodumyr
Supervisor: Krasnopolskyi Volodymyr

PRELIMINARY DESIGN OF THE AIRCRAFT
INITIAL DATA AND SELECTED PARAMETERS

Passenger Number	156.
Flight Crew Number	2.
Flight Attendant or Load Master Number	4.
Mass of Operational Items	1794.37 kg
Payload Mass	20050.80 kg
Cruising Speed	828. km/h
Cruising Mach Number	0.7719
Design Altitude	10.50 km
Flight Range with Maximum Payload	6800. km
Runway Length for the Base Aerodrome	3.30 km
Engine Number	2.
Thrust-to-weight Ratio in N/kg	2.8100
Pressure Ratio	30.00
Assumed Bypass Ratio	5.00
Optimal Bypass Ratio	5.00
Fuel-to-weight Ratio	0.3000
Aspect Ratio	9.48
Taper Ratio	4.00
Mean Thickness Ratio	0.120
Wing Sweepback at Quarter Chord	28.0 deg
High-lift Device Coefficient	1.16
Relative Area of Wing Extensions	0.040

Wing Airfoil Type – Supercritical
Winglets – Yes
Spoilers – Yes

Fuselage Diameter	3.95 m
Fineness Ratio	8.57
Horizontal Tail Sweep Angle	29.0 deg
Vertical Tail Sweep Angle	34.0 deg

CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point	0.49652
Induce Drag Coefficient	0.00914

ESTIMATION OF THE COEFFICIENT Dm = Mcritical – Mcruise

Cruising Mach Number	0.77187
Wave Drag Mach Number	0.78886
Calculated Parameter Dm	0.01700

Wing Loading in kPa (for Full Wing Area):

At Takeoff	6.139
At Middle of Cruising Flight	5.094
At the Beginning of Cruising Flight	5.922

Drag Coefficient of the Fuselage and Nacelles	0.01103
Drag Coefficient of the Wing and Tail Unit	0.00915
Drag Coefficient of the Airplane:	
At the Beginning of Cruising Flight	0.03187
At Middle of Cruising Flight	0.03039
Mean Lift Coefficient for the Ceiling Flight	0.49652
Mean Lift-to-drag Ratio	16.34098
Landing Lift Coefficient	1.687
Landing Lift Coefficient (at Stall Speed)	2.531
Takeoff Lift Coefficient (at Stall Speed)	2.062
Lift-off Lift Coefficient	1.505
Thrust-to-weight Ratio at the Beginning of Cruising Flight	0.552
Start Thrust-to-weight Ratio for Cruising Flight	2.188
Start Thrust-to-weight Ratio for Safe Takeoff	2.739
Design Thrust-to-weight Ratio	2.875
Ratio Dr = Rcruise / Rtake-off	0.799

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

Takeoff	36.8672
Cruising Flight	58.6058
Mean cruising for Given Range	58.6058

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.03468
Block Fuel	0.29960

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.10634
Horizontal Tail	0.00863
Vertical Tail	0.00852
Landing Gear	0.03671
Power Plant	0.08870
Fuselage	0.06798
Equipment and Flight Control	0.12725
Additional Equipment	0.00331
Operational Items	0.02165
Fuel	0.33428
Payload	0.19672

Airplane Takeoff Weight	82867. kgf
Takeoff Thrust Required of the Engine	119.14 kN

Air Conditioning and Anti-icing Equipment Weight Fraction	0.0218
Passenger Equipment Weight Fraction (or Cargo Cabin Equipment)	0.0153
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.0065
Furnishing Equipment Weight Fraction	0.0121
Flight Control Weight Fraction	0.0060
Hydraulic System Weight Fraction	0.0165

Electrical Equipment Weight Fraction	0.0322
Radar Weight Fraction	0.0031
Navigation Equipment Weight Fraction	0.0047
Radio Communication Equipment Weight Fraction	0.0023
Instrument Equipment Weight Fraction	0.0054
Fuel System Weight Fraction	0.0099

Additional Equipment:

Equipment for Container Loading	0.0000
No typical Equipment Weight Fraction	0.0033
(Build-in Test Equipment for Fault Diagnosis, Additional Equipment of Passenger Cabin)	

TAKE-OFF DISTANCE PARAMETERS

Airplane Lift-off Speed	290.66	km/h
Acceleration during Takeoff Run	2.22	m/s*s
Airplane Take-off Run Distance	1466.	m
Airborne Take-off Distance	578.	m
Take-off Distance	2045.	m

CONTINUED TAKE-OFF DISTANCE PARAMETERS

Decision Speed	276.13	km/h
Mean Acceleration for Continued Take-off on Wet Runway	0.26	m/s*s
Take-off Run Distance for Continued Take-off on Wet Runway	2520.26	m
Continued Take-off Distance	3098.64	m
Runway Length Required for Rejected Take-off	3211.30	m

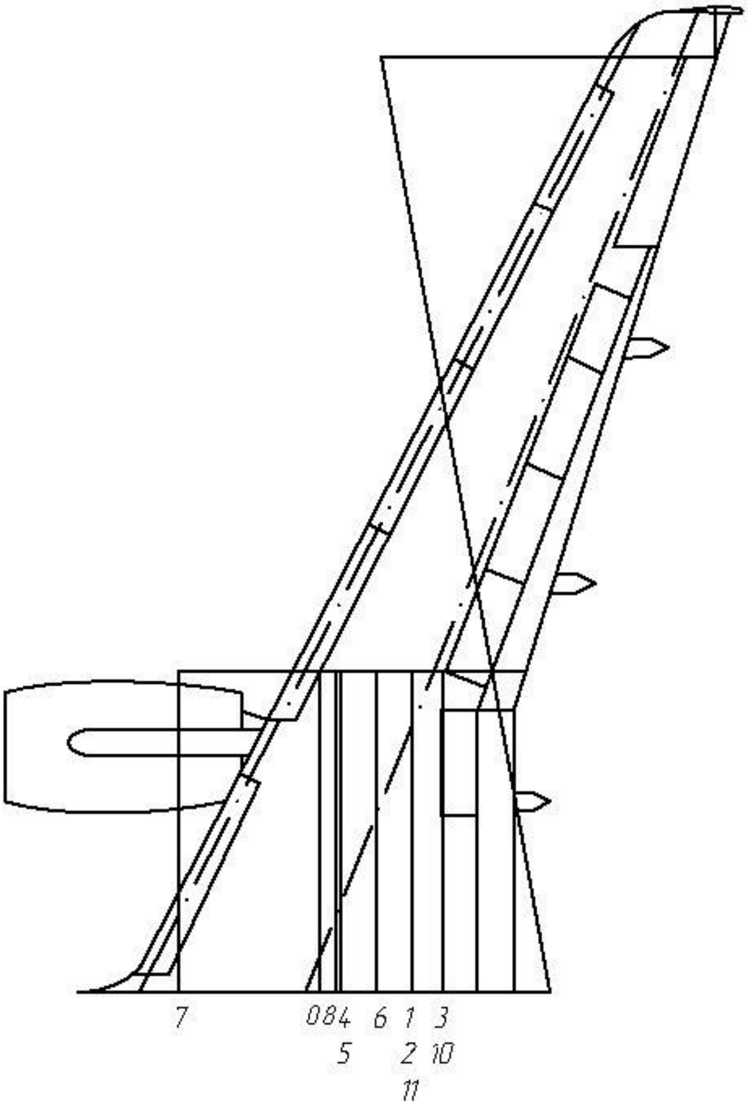
LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight	62393.	kg
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight	20.8	min
Descent Distance	47.92	km
Approach Speed	256.17	km/h
Mean Vertical Speed	2.05	m/s
Airborne Landing Distance	520.	m
Landing Speed	241.17	km/h
Landing run distance	775.	m
Landing Distance	1294.	m
Runway Length Required for Regular Aerodrome	2161.	m
Runway Length Required for Alternate Aerodrome	1838.	m

ECONOMICAL EFFICIENCY

The equipped aircraft mass to payload mass ratio	2.3677	
The mass of empty equipped aircraft per 1 passenger	247.43	kg/p
Relative performance with full load	439.67	km/h
Aircraft performance with maximum payload	13022.4	kg*km/h
Average time fuel consumption	2916.520	kg/h
Average distance fuel consumption	3.65	kg/km
Average fuel consumption for ton-kilometer	223.963	g/t*km
Average fuel consumption for passenger-kilometer	20.6507	g/p*km
Approximate evaluation of relative expenses for ton-km	0.3077	$/t*km

Appendix B



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Center of gravity of the wing

Ch	Sheet	Document No	Sign.	Date
Performed		Helenko V.V.		
Checked		Maslak T.P.		
Reviewed				
Approved				

Letter	Weight	Scale

Sheet 1 | Sheet 2

Appendix B

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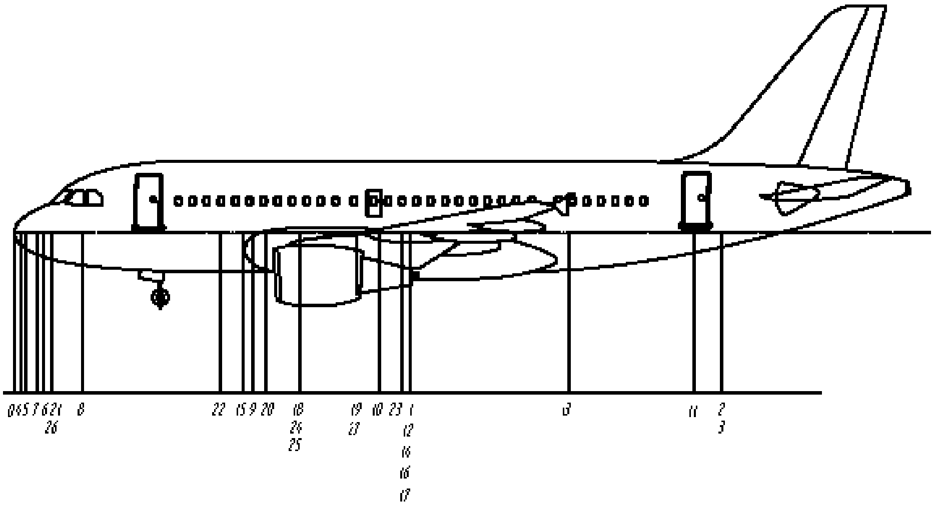
Appenoix C



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Revised				
Approved				

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Center of gravity of the fuselage

Letter	Weight	Scale

Sheet 1 | Sheet 2

Appenoix C

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