МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
КАФЕДРА КОНСТРУКЦІЇ ЛІТАЛЬНИХ АПАРАТІВ

ДОПУСТИТИ ДО ЗАХИСТУ
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__________ Сергій ІГНАТОВИЧ
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ЗІ СПЕЦІАЛЬНОСТІ
«АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА»

Тема: «Інноваційна система безпеки та порятунку для пасажирських літаків»

Виконавець: ___________**Артур ШПАК**

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Київ 2022

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

DEPARTMENT OF AIRCRAFT DESIGN

PERMISSION TO DEFEND
Head of the department,
D.Sc., professor
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«___» _________ 2022.

MASTER DEGREE THESIS
ON SPECIALITY
"AVIATION AND SPACE ROCKET TECHNOLOGY"

Topic: "Innovative safe and rescue system for passenger aircraft"

Prepared by: ___________**Artur SHPAK**

Supervisor: PhD, associate professor ___________**Volodymyr KRASNOPOLSKYI**

Labor protection adviser:
PhD, associate professor ___________**Katerina KAZHAN**

Environmental protection adviser:
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PhD, associate professor ___________**Volodymyr KRASNOPOLSKYI**

Kyiv 2022

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет аерокосмічний

Кафедра конструкції літальних апаратів

Освітньо-кваліфікаційний ступінь «Магістр»

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Освітня-професійна програма «Обладнання повітряних суден»

ЗАТВЕРДЖУЮ
Завідувач кафедри
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«___» __________ 2022 р.

ЗАВДАННЯ
на виконання дипломної роботи студента
Шпака Артура Петровича

1. Тема роботи: «Інноваційна система безпеки та порятунку для пасажирських літаків», затверджена наказом ректора від 05 жовтня 2022 року №1861/ст.

2. Термін виконання проекту: з 06 жовтня 2022 р. по 30 листопада 2022 р.

3. Вихідні дані до проекту: крейсерська швидкість V_{cr} = 860 км/год, дальність польоту L = 8000 км, крейсерська висота польоту H_{op} = 10 км.

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

5. Перелік обов’язкового графічного матеріалу: загальний вигляд літака (А1×1), компонувальне креслення фюзеляжу (А1×1), модель інноваційної системи безпеки та порятунку (А1×1).

6. Календарний план-графік

№ пор.	Завдання	Термін виконання	Відмітка про виконання
1	Огляд літератури про екстрені посадки літака на різні поверхні, розробка подушки безпеки.	06.10.2022-18.10.2022	

2	Вибір технічних характеристик для прототипу подушки безпеки.	19.10.2022-29.10.2022	
3	Аналіз прототипу подушки безпеки в умовах посадки.	30.10.2022-07.11.2022	
4	Моделювання системи безпеки та порятунку в фюзеляжі, розрахунок ефективності прототипу.	06.10.2022-31.10.2022	
5	Виконання розділів, присвячених охороні навколишнього середовища та праці.	01.11.2022-04.11.2022	
6	Оформлення кваліфікаційної роботи.	05.11.2022-10.11.2022	

7. Консультанти з окремих розділів:

Розділ	Консультанти	Дата, підпис	
		Завдання видав	Завдання прийняв
Охорона праці	к.т.н., доцент Катерина Кажан		
Охорона навколишнього середовища	к.т.н., професор Леся Павлюх		

8. Дата видачі завдання: «5» жовтня 2022 року.

Керівник дипломної роботи ____________Володимир КРАСНОПОЛЬСЬКИЙ

(підпис керівника)

Завдання прийняв до виконання ____________Артур ШПАК

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NATIONAL AVIATION UNIVERSITY
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Educational degree "Master"
Specialty 134 "Aviation and space rocket technology"
Educational professional program "Aircraft equipment"

APPROVED BY
Head of the department D.Sc., prof.
_____Sergiy IGNATOVYCH
"___" __________ 2022.

TASK
for the bachelor thesis
Shpak Artur

1. Topic: "Innovative safe and rescue system for passenger aircraft" approved by the Rector's order №1861 "05" October 2022 year.
2. Period of work execution: since 05 October 2022 year till 30 November 2022 year.
3. Initial data: cruise speed V_{cr} = 860 km/h, flight range L = 8000 km, operating altitude H_{op} = 10 km.
4. Content: 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: introduction and calculation of the safe and rescue system.
5. Required material: general view of the airplane (A1×1), layout of the airplane (A1×1), a model of an innovative safety and rescue system (A1×1).
6. Thesis schedule

№	Task	Time limits	Done
1	Review of literature on emergency landings of aircraft on various surfaces, development of airbags.	06.10.2022-18.10.2022	
2	Selection of technical characteristics for the airbag prototype.	19.10.2022-29.10.2022	
3	Analysis of the airbag prototype in landing conditions.	30.10.2022-07.11.2022	
4	Modeling of the safety and rescue system in the fuselage, calculation of the efficiency of the prototype.	06.10.2022-31.10.2022	
5	Implementation of parts dedicated to environmental and labor protection.	01.11.2022-04.11.2022	
6	Completion of the qualification work.	05.11.2022-10.11.2022	

7. Special chapter adviser:

Chapter	Consultants	Consultants	
		Task Issued	Task Recieved
Labor protection	PhD, associate professor Katerina KAZHAN		
Environmental protection	PhD, professor Lesya PAVLYUKH		

8. Date: "5" October 2022 year.

Supervisor _____________Volodymyr KRASNOPOLSKYI

Student _____________Artur SHPAK

РЕФЕРАТ

Пояснювальна записка дипломної роботи магістра «Інноваційна система безпеки та порятунку для пасажирських літаків»:

56 сторінок, 6 рисунків, 8 таблиць, 12 літературних посилань

Ця дипломна робота присвячена розробці системи безпеки та порятунку пасажирського літака під час екстреної посадки, що відповідає міжнародним стандартам польотів. В спеціальній частині описано розробку і застосування нового обладнання, а саме подушок безпеки, що зменшує навантаження при посадці на воду та землю, тим самим зменшуючи імовірність його пошкодження та підвищення безпечності при аварійній посадці літака. В дослідженні застосовано метод порівняльного аналізу літаків-прототипів для вибору найбільш обґрунтованих технічних рішень, а також методи інженерних розрахунків для отримання основних параметрів проектованого літака.

В спеціальній частині застосовано метод використання подушок безпеки, аналіз та вибір найбільш технічних рішень, а також розрахунок для отримання основних параметрів обладнання літака. Практичне значення результатів магістерської роботи полягає в тому, що результати роботи можуть бути використані як спеціальний комплект модернізації літака, без суттєвих змін конструкції фюзеляжу.

Пасажирський літак, аванпроект літака, центрування літака, подушка безпеки, компонування подушки, посадка на воду, аварійна посадка, розрахунок навантаження

ABSTRACT

Master degree thesis « Innovative safe and rescue system for passenger aircraft»

56 pages, 6 figures, 8 tables, 12 references

This thesis is devoted to the development of a safety system and rescue of a passenger aircraft during an emergency landing that meets international flight standards. The special part describes the development and application of new equipment, namely airbags, which reduce the load when landing on water and land, thereby reducing the probability of its damage and increasing safety during an emergency landing of an aircraft. The research uses the method of comparative analysis of prototype aircraft to select the most reasonable technical solutions, as well as methods of engineering calculations to obtain the main parameters of the designed aircraft.

In a special part, the method of using airbags, the analysis and selection of the most technical solutions, as well as the calculation for obtaining the main parameters of the aircraft equipment are applied. The practical significance of the results of the master's work is that the results of the work can be used as a special kit for the modernization of the aircraft, without significant changes in the fuselage design.

Passenger aircraft, preliminary design, center of gravity calculation, airbag, airbag composition, ditching on water, emergency landing, loading calculation

CONTENT

INTRODUCTION

Nowadays aviation is one of the most demanded and developed branches of the transport system. Therefore, there are different types of aircraft. This is justified by the need for: transportation of goods, passengers, military equipment to distant and hard-to-reach places.

In this regard, it is important to create an aircraft that will meet modern standards, large capacity and flight range.

The main performances are taken: cruise speed V_{cr} = 860 km/h, flight range L= 8000 km, operating altitude H_{op} = 10 km, 550 passenger capacity.

The purpose of this diploma work is to create an aircraft that will meet the following requirements:

-comfortability

-high safety level

-reliability and ease of operation

-reducing harm to the environment

-easy maintenance support

1. PROJECT PART. PRELIMINARY DESIGN OF THE LONG-RANGE AIRCRAFT

1.1 Analysis of prototypes and short description of designing aircraft

1.1.1 Overview general performances

During design of a new aircraft, the choice of optimal design parameters depends on the area of application, passenger and cargo capacity, assembly method, economic requirements for material consumption and design complexity.

Aerodynamic calculation, calculation of geometric parameters and centering of the fuselage and wing are used to create the final look of the exterior and interior of the aircraft.

For designed aircraft there were chosen the prototypes in range of 500-600 passengers and long-range of usage. Such aircraft like Airbus A380, Boeing 747-8 and Boeing 747-400 will compete with designed one in chosen market segment. Performances of prototypes are presented in table 1.1.

Table 1.1

Performances of prototypes

PARAMETER	PLAINES		
	Airbus A380	Boeing 747-8	Boeing 747-400
The purpose of airplane	Passenger	Passenger	Passenger
Crew/flight attend. persons	2/15	2/11	2/11
Maximum take-off weight, m_{tow}, kg	365508 kg	447696 kg	412770 kg
Maximum payload, $m_{p\ max}$, kg	67925 kg	82100 kg	67177 kg
Passengers	550	605	550
The flight altitude, V_{fal}, m	13100 m	13720 m	13720 m

Ending of the table 1.1

Flight range m_{fmax}, km	8000 km	10930 m	11300 m
Take-off distance $L_{to\ d.}$, m	2374 m	2970 m	2940 m
Number and type of engines	4 × GP7270	4 × GEnx-2B67	4 × RR RB211-524G
The shape of the fuselage cross-section	circular	circular	circular
Fineness ratio	10	10,56	10,56
Extension of the fuselage	55,15 m	59,25 m	56,39 m
Extending the nose and tail unit part	27,66 m	28.2 m	27,1 m
Sweepback angle at 1/4 chord line, °	32°	37°	37,5°

For the successful formation of the layout, a combination of the effective characteristics of all three aircraft prototypes is used. The A380 was chosen as the basis for the designed airplane, as it meets all safety requirements and is the most economically efficient among long-range large liners.

1.1.2 Brief description of the main parts of the aircraft

The plane is a double-deck wide-body low-wing monoplane with four turbofan engines attached under the wing. The undercarriage consists of four main landing gear and one front gear, with the two inboard landing gear each supporting four wheels. A swept wing with a high aspect ratio and leading edge extension is used. Along the leading edge of the wing is located high-lift device, on the trailing edge there are two slotted flaps with a fixed deflector and slotted ailerons with horn and axial balance.

Fuselage has circular cross section. Empennage is single-fin with fixed stabilizer mounted on the fuselage. Rudders and elevators are double-link, with horn and axial balance.

1.1.2.1 Wing

The aircraft is made according to the scheme of a low-wing. The 36-meter wings are designed for a maximum take-off weight of over 650 tons. Moreover, the wing area is 845 m^2.

The wing consists of nose, central (middle), tail parts and ailerons, slotted flaps, end fairings. The central part are made of solid-pressed large-sized panels and spars. It helps wing structure to increase its reliability and reduce its weight, also simplifies the process of its assembly. The low-wing is box type wing that include attachment fitting to fuselage and wing panel. The wing box is a two-spar structure made of high-strength aluminum alloy. There are fuel tanks in the middle part of the wings.

The low-wing scheme is the most often used for passenger aircraft because it provides greater safety in comparison with other configuration during an emergency landing on the ground or water. When aircraft is landing on the ground with the gear retracted, the wing absorbs the impact energy, protecting the passenger cabin. When landing on water, the aircraft is submerged in the water at wing level, which gives the fuselage additional balance and simplifies the evacuation of passengers.

An important advantage of the low-wing scheme is the lowest weight of the structure, because the main landing gear is the most often mounted to the wing and their dimensions and weight are less than in a high-wing aircraft. The wings incorporate wingtip fences that extend above and below the wing surface. These increase fuel efficiency and range by reducing induced drag. The wingtip fences also reduce wake turbulence, which endangers following aircraft.

The so-called supercritical airfoil (airfoils of double curvature) are used that in comparison with conventional airfoil of the same relative thickness, have higher (by 0.08 ... 0.1) M_{crit} values. The supercritical airfoil serves to increase the values of M_{cr}. It has a large leading edge radius, an almost flat top and convex bottom and a thin, curved tail. The distribution of pressures along the airfoil leads to a decrease in the velocities in sections with the maximum airfoil thickness, hence the increase in the M_{cr} values by 0.07 ... 0.08. Since the CP in such a airfoil is displaced to its tail, it creates a large descend moment, which requires deflection of the elevators (stabilizer) for balancing.

1.1.2.2 Fuselage

The fuselage of the aircraft is an full-metal semimonocoque design with a longitudinal set of stringers and beams, a transverse set of frames and working skin with reinforcements in the areas of cut-outs for hatches, doors, windows and aircraft equipment.

The fuselage is divided into nose (front), middle and tail (rear) sections. The cockpit is located on the lower deck of fuselage nose part, which is separated by a partition from the passenger cabin. There is a canopy with sliding window in the front part of the cockpit. There is an emergency hatch is located in the upper part. The window of the cockpit canopy provides great visibility to the pilots in flight. There are seats for the captain and first-officer in the cockpit. There are side steak for control of aircraft attitude. Flight-navigational displays for monitoring the operation of the power plant signaling devices and other systems are mounted on the dashboard. The passenger cabin is located in middle part of fuselage. On this aircraft, the fuselage is divided into two floors. There are 8 doors (entrance and emergency).

1.1.2.3 Tail unit

The horizontal tail is located behind the wing. This scheme has become widespread in civil aircraft. Empennage of the aircraft is made cantilever with one centrally located fin. The elevator is made of double-link and is divided in two-section. The rudder is made of two-link and is divided in three-section.

The main advantages of this design are:

- The effective use of high-lift device of the wing;
- Provides balance of aircraft, when flaps are extended;
- The location of tail unit behind wings improves the visibility to pilots and reduces the area of stabilizers.

The geometrical parameters are chosen so that the crisis flow around the empennage occurs later than on the wing. This allows the aircraft to be removed from the crisis flow and increases flight safety.

The stabilizer is made of composite materials. The fin joint is made by means of fittings, which are made of aluminum alloy. In designed aircraft, part of the fuel is placed in the tail unit.

1.1.2.4 Landing gear

The landing gear provides the aircraft with high stability during the take-off and run, good controllability when moving on the ground and effective braking of the wheels. The aircraft landing gear consists of four main gear (two on the fuselage and two on the wings) and one front gear under the cockpit.

Each main landing gear contain shock absorber and is equipped with four wheels with hydraulic disc brakes and a wheel cooling system. The main gears are retracted into the fairing wheel well. The nose landing gear consists of shock absorber with two non-braking wheels. The front gear is retracted into the front wheel well of the fuselage landing gear. The nose landing gear is used to steering the aircraft. The wheel well are fully closed by doors, when landing gear are extended or retracted. The wheel braking system is designed for braking, taxiing and landing run of aircraft.

1.1.2.5 Power plant

In accordance with the performance of aerodynamic calculations for the aircraft design, the required maximum thrust at take-off mode is 365 kN. In accordance with this value was chosen the GP 7270. It is a two-spool dual rotor, axial airflow, high bypass ratio turbofan engine consisting of turbomachine and reduction gearbox modules connected by a drive shaft and integrated structural intake case. It has a single-stage fan, a five-stage low-pressure compressor, a nine-stage high-pressure compressor, a low-emission annular combustion chamber, a two-stage high-pressure turbine, and a six-stage low-pressure turbine.

The turbomachine is a three concentric shaft design incorporating two centrifugal compressors each driven separately by two-stage turbines and a six-stage power turbine.

The reduction gearbox features a twin lay shaft design with antifriction bearings and an offset propeller shaft. The combustion system is comprised of an annular reverse flow combustor, 14 piloted air blast fuel nozzles and two ignitors[2,3,7].

The general characteristics of this engine are presented in table 1.2

Table 1.2

Characteristics of engine GP7270

Type	Two-spool high bypass ratio turbofan
Compressor	24 swept wide-chord hollow titanium fan blades,; 5-stage low-pressure axial compressor; 9-stage HP axial compressor
Weight	14,797 lb 6,712 kg
Thrust	81,500 lbf 363 kN
Length	194 in (492 cm)
Bypass Ratio	8.8:1
Diameter	124 in (316 cm)
Overall Pressure Ratio	43.9:1

1.2 Aircraft layout calculation

1.2.1 Geometry calculations for the aircraft principles structural units

The determination of basic dimensions and operational requirements is the basis for calculation of aircraft layout.

The wing, fuselage, tail and landing gear are the main structural units from which the layout is folded. Moreover, this analytical part provides an opportunity to choose the interior layout.

To define the layout of the cabin, it is necessary to calculate the dimensions of the cabin in accordance with the requirements of the aircraft's capacity. The layout was implemented in accordance with both modern standards and advanced calculation methods.

1.2.1.1 Wing geometry calculation

Full wing area is:

$$S_w = \frac{m_0 \cdot g}{P_0}$$

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

$$S_w = \frac{365508 \cdot 9.8}{6809} \approx 527 \text{ m}^2$$

Wing span is:

$$I_w = \sqrt{S_w \cdot \lambda_w}$$

where λ_w – wing aspect ratio.

$$I_w = \sqrt{527 \cdot 8.16} = 65.55 \text{ m}$$

Root chord is:

$$b_0 = \frac{2S_w \cdot \eta_w}{(1+\eta_w) \cdot I_w}$$

where η_w – wing taper ratio.

$$b_0 = \frac{2 \cdot 527 \cdot 3}{(1+3) \cdot 65.55} = 1205 \text{ m}$$

Tip chord is:

$$b_t = \frac{b_0}{\eta_w}$$

$$b_t = \frac{12.05}{3} = 4.02 \text{ m}$$

Maximum wing thickness is:

$$C_{max}=C_w \cdot b_t$$

where c_w – medium wing relative thickness, m.

$$C_{max}=0.11 \cdot 4.02=0.4422 \text{ m}$$

On board chord is:

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

where D_f – fuselage diameter, m.

$$b_{ob}=12,05 \cdot \left(1-\frac{(3-1) \cdot 7,1}{3 \cdot 65,55}\right)=11.18 \text{ m}$$

For mean aerodynamic chord determination the geometrical method was used (fig. 1.1).

The geometrical method was used to determine the length of MAC. Thus, the mean aerodynamic chord is equal: b_{mac} = 8.7 m.

To choose the structure scheme of the wing it is necessary to determine the type of its internal design. The torsion-box type with two spars was chosen to meet the requirements of strength and at the same time to make the structure comparatively light.

For wing geometry estimation it is necessary to determine and calculate the main parameters of control surfaces.

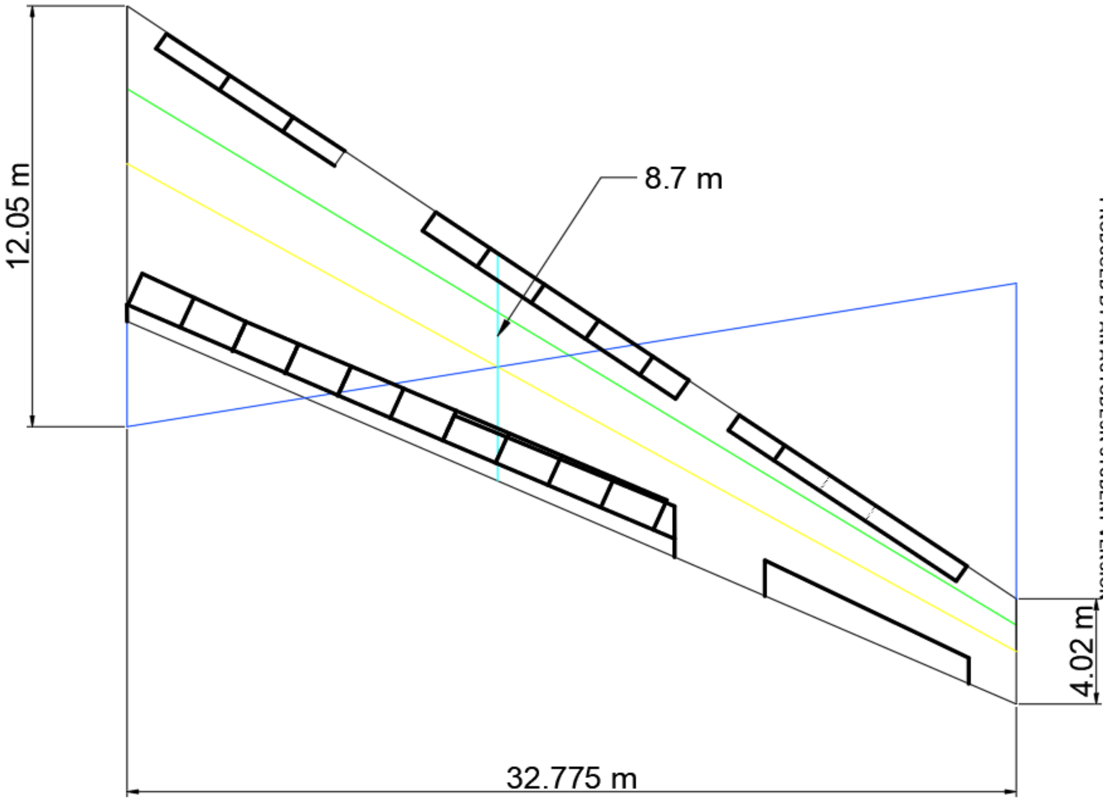


Fig. 1.1. Geometrical method of determination of mean aerodynamic chord.

Ailerons geometrical parameters are determined in the next order:

Ailerons span:

$$I_{ail}=0.35\cdot\frac{I_w}{2}$$

$$I_{ail}=0.35\cdot\frac{65.55}{2}=11.47 \text{ m}$$

Aileron chord:

$$b_{ail}=0.44\cdot b_t$$

$$b_{ail}=0.44\cdot 4.02=1.7688 \text{ m}$$

Aileron area:

$$S_{ail}=0.065\cdot\frac{S_w}{2}$$

$$S_{ail}=0.065\cdot\frac{527}{2}=17.11\ \text{m}^2$$

Increasing of aileron span and chord more than these values are not convenient because with the increase of aileron span the increase of the aileron's coefficient decreases as well as the high-lift devices span. In the case of aileron chord, its value increase lead to the decreasing of wing box width.

Aerodynamic balance of the aileron:

$$\text{Axial } S_{ax.ail}\leq(0.3\ldots0.31)\cdot S_{ail}$$

$$S_{ax.ail}=0.3\cdot17.11=5.13\ \text{m}^2$$

Area of ailerons trim tab for four engine airplane:

$$S_{tail}\leq(0.07\ldots0.08)\cdot S_{ail}$$

$$S_{tail}=0.07\cdot17.11=1.2\ \text{m}^2$$

Range of aileron deflection: upward $\delta_{ail} \geq 20°$, downward $\delta_{ail} \geq 10°$.

1.2.1.2 Fuselage layout

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

In case of geometrical calculation, it is necessary to take into account the expected aerodynamic characteristics of designed airplane, typical resistances during normal and

extreme flight conditions in accordance with estimated purpose. Airplane's fuselage geometry should allow to avoid high values of parasitic, skin friction and wave drags, withstand the aerodynamic loads and have as greater as possible safety factor value. To decrease form and wave drug and to provide necessary strength characteristics avoiding the stress concentrators in fuselage cross-section the round shape was chosen.

Another part of fuselage calculation as interior scheme creation is based on the required capacity of designed aircraft. Besides that, the requirements of ergonomics and sanitary standards must be considered for passenger aircrafts.

The next steps are necessary to calculate the main geometrical characteristics of the fuselage and consequently to obtain its outline.

Nose part length is:

$$I_{nfp}=1.9 \cdot D_f$$

$$I_{nfp}=1.9 \cdot 7.1=13.49 \text{ m}$$

Fuselage length is:

$$I_f=\lambda_f \cdot D_f$$

where: λ_f – fuselage fineness ratio.

$$I_f=10 \cdot 7.1=71 \text{ m}$$

Fuselage nose part fineness ratio is:

$$\lambda_{fnp} = \frac{I_{fnp}}{D_f}$$

$$\lambda_{fnp}=\frac{13.49}{7.1}=1.9$$

Length of the fuselage rear part is:

$$I_{frp}=\lambda_{frp}\cdot D_f$$

where: λ_{frp} – fuselage fineness ratio.

$$I_{frp}=3\cdot 7.1=21.3 \text{ m}$$

For economic and business class passenger cabin the configuration of seats is in the one row (2+2+2).Width of the cabin is:

$$B_{cab}=n_{2chblock}\cdot b_{2chblock}+n_{aisle}\cdot b_{aisle}$$

where $n_{3chblock}$ – width of 2 chairs, m; $b_{3chblock}$ – number of 2 chair block; b_{aisle} – width of aisle, m; n_{aisle} – width of aisle, m.

$$B_{cab1fl}=3\cdot 1070+2\cdot 510+2\cdot 500=5.33 \text{ m}$$

$$B_{cab2fl}=3\cdot 1070+2\cdot 510+2\cdot 100=4.63 \text{ m}$$

$$B_{busscab}=3\cdot 1450+2\cdot 580+2\cdot 100=5.51 \text{ m}$$

Cabin height is:

$$H_{cab}=1.48+0.17B_{cab}$$

where B_{cab} – width of the cabin, m.

$$H_{cab1fl}=1.48+0.17\cdot 5.33=2.38 \text{ m}$$

$$H_{cab2fl}=1.48+0.17\cdot 4.63=2.26 \text{ m}$$

$$H_{busscab}=1.48+0.17\cdot 5.51=2.41 \text{ m}$$

The length of passenger cabin is:

$$L_{cab}=L_1+(n_{raws}-1)\cdot L_{seatpitch}+L_2$$

where L_1 – distance between the wall and the back of first seat, m; n_{rows} – number of rows; $L_{seat\ pitch}$ – seat pitch, m; L_2 – distance between the back of last seat and the wall, m.

$$L_{cab1fl}=1200+(50-1)\cdot 760+235=38.185 \text{ m}$$

$$L_{cab2fl}=1200+(31-1)\cdot 750+235=23.93 \text{ m}$$

$$L_{busscab}=1300+(12-1)\cdot 960+300=12.16 \text{ m}$$

1.2.1.3 Luggage compartment

The area of cargo compartment is:

$$S_{cargo}=\frac{M_{bag}}{0.4K}+\frac{M_{cargo\&mail}}{0.6K}=\frac{20\cdot 550}{0.4\cdot 600}+\frac{15\cdot 550}{0.6\cdot 600}=68.75 \text{ m}^2$$

Cargo compartment volume is:

$$V_{cargo}=v\cdot n_{pass}$$

where v – relative mass of baggage m^3, kg; n_{pass} – number of passengers.

$$V_{cargo}=0.17\cdot 550=93.5 \text{ m}^3$$

Luggage compartment design is similar to the prototype.

1.2.1.4 Galleys and buffets

Volume of buffets (galleys) is:

$$V_{galley}=(0.1\ldots 0.12)\cdot n_{pass}$$

where v – volume of buffets m^3; n_{pass} – number of passengers.

$$V_{galley}=0.11\cdot 550=60.5 \text{ m}^3$$

Area of buffets (galleys) is:

$$S_{galley}=\frac{V_{galley}}{H_{cab}}$$

$$S_{galley}=\frac{60.5}{2.38}=25.42 \text{ m}^2$$

Number of meals per passenger breakfast, lunch and dinner – 0.8 kg, tea and water – 0.4 kg. Buffet design is similar to prototype.

1.2.1.5 Lavatories

Number of toilet facilities is determined by the number of passengers and flight duration: with t > 4:00 one toilet for 40 passengers.

$$n_{lav} = 11$$

Area of lavatory:

$$S_{lav} = 1.6 \text{ m}^2$$

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

1.2.1.6 Layout and calculation of basic parameters of tail unit

The chosen tail unit scheme is conventional. This choice is based on all three prototypes empennage schemes.

To estimate the general tail unit outlines it is necessary to calculate the geometrical dimensions of vertical and horizontal stabilizers and dimensions of control surfaces. In general tail unit must to meet the requirements of aircraft stability and controllability.

Area of vertical tail unit is:

$$S_{VTU}=(0.12\ldots0.2)\cdot S_w$$

$$S_{VTU}=0.15\cdot527=78.99 \text{ m}^2$$

Area o horizontal tail unit is:

$$S_{HTU}=(0.18\ldots0.25)\cdot S_w$$

$$S_{HTU}=0.22\cdot527=115.85 \text{ m}^2$$

Determination of the elevator area and direction:

Altitude elevator area is:

$$S_{el}=k_{el}\cdot S_{HTU}$$

where k_{el} – relative elevator area coefficient.

$$S_{el}=0.3\cdot115.85=34.76 \text{ m}^2$$

Rudder area is:

$$S_{rud}=k_r \cdot S_{VTU}$$

where k_r – relative rudder area coefficient.

$$S_{rud}=0.4 \cdot 78.99=31.6 \text{ m}^2$$

Choose the area of aerodynamic balance:

$$M \geq 0.75, S_{eb} \approx S_{rb}=(0.18 \ldots 0.2) S_{el/rud}$$

Elevator balance area is:

$$S_{eb}=0.18 \cdot S_{el}$$

$$S_{eb}=0.22 \cdot 34.76=6.2568 \text{ m}^2$$

Rudder balance area is:

$$S_{rb}=0.2 \cdot S_{rud}$$

$$S_{rb}=0.2 \cdot 31.6=6.32 \text{ m}^2$$

The area of altitude elevator trim tab is:

$$S_{te}=0.06 \cdot S_{el}$$

$$S_{te}=0.08 \cdot 34.76=2.0856 \text{ m}^2$$

Area of rudder trim tab is:

$$S_{tr}=0.06 \cdot S_{rud}$$

$$S_{tr}=0.06 \cdot 31.6=1.896 \text{ m}^2$$

Root chord of horizontal stabilizer is:

$$b_{OHTU}=\frac{2S_{HTU} \cdot \eta_{HTU}}{(1+\eta_{HTU}) \cdot l_{HTU}}$$

where η_{HTU} – horizontal tail unit taper ratio; l_{HTU} – horizontal tail unit span.

$$\eta_{HTU}=2.5$$

$$l_{HTU}=(0.32 \ldots 0.5) \cdot l_w$$

$$l_{HTU}=0.4 \cdot 65.55=26.22 \text{ m}$$

$$b_{OHTU}=\frac{2 \cdot 115.85 \cdot 2.5}{(1+2.5) \cdot 26.22}=6.31 \text{ m}$$

Tip chord of horizontal stabilizer is:

$$b_{OHTU}=\frac{b_{OHTU}}{\eta_{HTU}}$$

$$b_{OHTU}=\frac{6.31}{2.5}=2.524 \text{ m}$$

Root chord of vertical stabilizer is:

$$b_{OVTU}=\frac{2S_{VTU}\cdot\eta_{VTU}}{(1+\eta_{VTU})\cdot I_{VTU}}$$

where η_{VTU} – vertical tail unit taper ratio; l_{VTU} – vertical tail unit span.

$$\eta_{VTU}=2$$

$$l_{VTU}=(0.14...0.2)\cdot l_w$$

$$l_{VTU}=0.18\cdot 65.55=11.8 \text{ m}$$

$$b_{OVTU}=\frac{2\cdot 78.99\cdot 2}{(1+2)\cdot 11.8}=8.93 \text{ m}$$

Tip chord of vertical stabilizer is:

$$b_{OVTU}=\frac{b_{OVTU}}{\eta_{VTU}}$$

$$b_{OVTU}=\frac{8.93}{2}=4.465 \text{ m}$$

1.2.1.7 Landing gear design

To estimate the landing gear outline in this project it is necessary to calculate the location of every strut in relatively to each other, to determine the loads on landing gear system, and its location considering center of gravity of an airplane.

In this layout the principal scheme of landing gear is fully based on the prototype data. As in the case with the tail unit it is necessary to provide the aircraft with the stable and controllable base during operation on the ground including landing and take-off. The general characteristics of the nose and main gears are presented in table 1.3 and 1.4.

Main wheel axes offset is:

$$e=0.17 \cdot b_{MAC}$$

where b_{MAC} – mean aerodynamic chord.

$$e=0.17 \cdot 8.7=1.48 \text{ m}$$

Landing gear wheel base is:

$$B=k_b \cdot L_f$$

where k_b – wheel base calculation coefficient.

$$B=0.35 \cdot 71=24.85 \text{ m}$$

Front wheel axial offset is:

$$d_{ng}=B-e$$

$$d_{nd}=24.85-1.48=23.37 \text{ m}$$

Wheel track is:

$$T=k_T \cdot B$$

where k_b – wheel track calculation coefficient.

$$T=0.43\cdot 24.85=10.69 \text{ m}$$

Nose wheel load is:

$$P_{NLG}=\frac{(9.81\cdot e\cdot k_g\cdot m_0)}{(B\cdot z)}$$

where K_g – dynamics coefficient; z – number of wheels.

$$P_{NLG}=\frac{(9.81\cdot 1.48\cdot 1.5\cdot 365508)}{(24.85\cdot 2)}=160106 \text{ N}$$

Main wheel load is equal:

$$P_{MLG}=\frac{(9.81\cdot (B-e)\cdot m_0}{(B\cdot n\cdot z)}$$

where n – number of main landing gear struts.

$$P_{MLG}=\frac{(9.81\cdot (24.85-1.48)\cdot 365508)}{(24.85\cdot 4\cdot 4)}=210759 \text{ N}$$

Table 1.3

Nose Gear

Size	Construction			Service Rating				Tread Design/Trademark	Weight (Lbs)
	Ply Rating	TT or TL	Rated Speed(mph)	Rated load(Lbs)	Rated Inflation(Psi)	Max Breaking Load(Lbs)	Max Bottoming Load(Lbs)		
H 40x14.	26	TL	225	36800	220	53360	99360	Flight Leader	71

5-18									

Ending of the table 1.3

Inflated Dimensions (in)				Static Loaded Radius(in)	Aspect Ratio	Wheel(in)			
Outside DIA		Section Width				Width Between Flanges	Specified Rim Diameter	Flange Height	Min Ledge Width
Max	Min	Max	Min						
40	39.1	14.5	13.75	16.64	0.726	9.5	19	1.4	3.1

Table 1.4

Main gear

Size	Construction			Service Rating				Tread Design/Trademark	Weight (Lbs)
	Ply Rating	TT or TL	Rated Speed(mph)	Rated load(Lbs)	Rated Inflation(Psi)	Max Breaking Load(Lbs)	Max Bottoming Load(Lbs)		
46x16	32	TL	225	48000	245	72000	144000	Flight Leader	93

Inflated Dimensions (in)				Static Loaded Radius(in)	Aspect Ratio	Wheel(in)			
Outside DIA		Section Width				Width Between Flanges	Specified Rim Diameter	Flange Height	Min Ledge Width
Max	Min	Max	Min						
45.25	44.3	16	15.05	19	0.797	13.25	20	1.88	3.4

1.3 Determination of the aircraft center of gravity position

1.3.1 Determination of centering of the equipped wing

The distance from the main aerodynamic chord to the center of gravity of the airplane is called the centering. During the changing of the aircraft loading variants or because of the changing of weight during flight the position of aircraft center of mass is changing. The moving of the cargo inside the aircraft leads to changing of center of mass position too [1,3].

The centering is important aircraft characteristic as it affects on the balancing, stability and controllability of the aircraft. That’s why it is necessary to keep it inside strict limits.

To calculate the centering, it is necessary to determine the mass of main structural units and devices. The list of the units masses for the aircraft given in the table 1.5. The mass of aircraft is 280000 kg. The trim sheet of equipped wing masses are presented in table 1.5.

The longitudinal static stability of the aircraft is determined by the location of its center of mass relatively to the focuses. The closer the center of mass is to the nose part of the aircraft, the more longitudinally stability the aircraft have. Coordinates of the center of gravity for the equipped wing is determined by the formula (1.1).

$$X_w' = \frac{\Sigma m_i' X_i}{\Sigma m_i'} \tag{1.1}$$

Table 1.5

Trim sheet of equipped wing masses

N	Name	Mass		C.G. coordinates x_i (m)	Moment $m_i x_i$ (kgm)
		Units	total mass m_i (kg)		
1	Wing (structure)	0,0979	35772,27	3,66	130753,73
2	Fuel system	0,0130	4751,60	3,78	17938,11
3	Control system, 30%	0,0011	416,68	5,22	2175,76
4	Electrical equipment	0,0056	2061,47	0,87	1794,05
5	Anti-icing system 70%	0,0136	4963,60	0,87	4319,71
6	Hydraulic system, 70%	0,0087	3172,61	5,22	16566,32
7	Equipped wing without fuel and LG	0,1661	51138,22	3,39	173547,69
8	Nose landing gear, 40%	0,0097	3551,82	-19,51	-69299,64
9	Main landing gear	0,0292	10655,47	5,34	56889,56
10	Fuel	0,3774	137957,34	3,78	520812,43
	Equipped wing	0,5824	203302,86	3,35	681950,04

1.3.2 Determination of the centering of the equipped fuseIage

The list of the unit for the aircraft is given in table 1.6. The center gravity coordinates of the equipped fuselage is determined by the formula (1.2) The trim sheet of equipped fuselage masses are presented in table 1.6.[1,3].

$$X_f' = \frac{\Sigma m_i' X_i}{\Sigma m_i'} \qquad (1.2)$$

Table 1.6

Trim sheet of equipped fuselage masses

№	Objects	Mass		Coordinates of CG	Moment (kgm)
		Units	Total (kg)		
1	Fuselage	0,0875	25314,625	34,72	878923,78
2	Horizontal TU	0,01152	3332,8512	60,29	200937,5988
3	Vertical TU	0,00877	2537,2487	60,29	152970,7241
4	Instrument panel	0,0028	1023,42	3,11	3182,84
5	Aero navigation equipment	0,0024	877,22	1,12	982,49
6	Power unit	0,0915	33451,29	28,89	966407,83
7	Radio equipment	0,0012	438,61	2,52	1105,3
8	Lavatory	0,0027	990	46,41	45945,9
9	Coatroom	0,0010	378,89	21,10	7994,56
10	Galley	0,0029	1045	32,54	34004,3
11	Cargo equipment	0,0185	6761,9	31	209618,84
12	Control system, 70%	0,0027	972,25	35,5	34514,92
13	Electrical equipment	0.0132	4810,09	35,5	170758,03
14	Hydraulic system, 30%	0,0037	1359,69	42,6	57922,78
15	Covering	0,0055	2010,29	35,5	71365,44
16	Chemical liquid	0,003	1100	46,41	51051
17	Anti-icing system 30%	0,0058	2127,26	49,7	105724,65
18	Seats of passenger	0,0316	11550	35,41	408985,5
19	Rescue equipment	0,0075	2750	35,41	97377,5
20	Seats of crew	0,0010	357	4,85	1731,45
	Equipped fuselage without payload	0,2828	103356,18	33,73	3485877,02
	Payload				
21	Crew	0,0035	1275	4,85	6183,75
22	Baggage	0,0447	16323,96	31	506042,76

23	Passengers	0,1129	41250	35,41	1460662,5
	Equipped fuselage with payload	0,4438	162205,14	33,65	5458766,03

1.3.3 Calculation of center of gravity positioning variants

The list of mass objects for center of gravity variants calculation given in Table 1.7 and center of gravity variants calculation given in table 1.8 completes on the base of both previous tables [1,3].

The mean aerodynamic chord center of gravity is:

$$X_{MAC}=\frac{m_f \cdot x_f+m_w \cdot x_w-m_0 \cdot c_n}{m_0-m_w} = 37.28 \text{ m} \tag{1.3}$$

where m_0 – aircraft takeoff mass, kg; m_f – mass of equipped fuselage, kg; m_w – mass of equipped wing, kg.

Table 1.7

Calculation of center of gravity positioning variants

Name	Mass, kg	Coordinates	Moment
Object	m_i	C.G. M	kgm
Equipped wing without fuel and L.G.	51138,22	35,8	1830937,54
Nose landing gear (extended)	3551,82	12,9	45814,98
Nose landing gear (extended)	10655,47	37,75	402233,41
Fuel	137957,34	36,19	4992009,8
Equipped fuselage	1033556,18	33,73	3485877,02
Passengers	41250	35,41	1460662,5
Baggage of passenger	16323,96	31	506042,76
Cargo	16403,877	25	410096,9
Crew	1275	4,85	6183,75
Nose landing gear (retracted)	1038,33359	8,57076	8899,308
Main landing gear (retracted)	9345,00231	36,34076	339604,5
Fuel whilst landing	34489,33	36,19	1248002,45

Table 1.8

Aircrafts center of gravity position variants

№	Variants of the loading	Mass, kg	Moment of the mass, кg*m	Centre of the mass, *m*	Centering, %
1	Take-off mass (L.G. extended)	365508	12729761,76	34,83	27,78
2	Take-off mass (L.G. retracted)	365508	12725499,57	34,82	27,65
3	Landing variant (L.G. extended)	262040	8985754,41	34,29	21,62
4	Transportation variant (without payload)	307934,04	10758794,31	34,94	29,06
5	Parking variant (without fuel and payload)	168701,7	5764862,95	34,17	20,25

Conclusion to the project part

The aircraft meets the requirements for basic geometric parameters, such as operational purpose, planned number of passengers and cargo, speed, flight altitude, landing and take-off conditions.

Geometric alignment parameters correspond to the selected prototype. This allows us to conclude that the developed aircraft will successfully compete with other models in the selected market segment.

In addition, the GP7270 engine was selected based on the efficiency requirements of the aircraft being designed.

2. SPECIAL PART. INNOVATIVE SAFE AND RESCUE SYSTEM

2.1 Basic concept

In aviation, emergency situations occur when the landing gear fails (emergency landing), it is impossible to reach the runway or landing on the water surface(ditching). Such situations are rare, but they are still very risky. The success of the landing directly depends on how well the pilot and crew are able to perform the necessary flight manual procedures in emergency situations. When the aircraft is ditching, contact between the water surface and the aircraft fuselage must be achieved according to the target angle of inclination relative to the horizontal (pitch angle). In this way, it is possible to achieve the best dynamic behavior at impact, minimizing the loads on the structure and avoiding the destruction of the aircraft.

During an emergency landing, the engines may run at low speeds or even fail. To support the operation of the main (elevator and ailerons) and secondary (flaps and rudder) control surfaces, additional power is activated with the help of buffer batteries. Such batteries are usually limited in duration of work and power. Due to the emergency landing, the control of the aircraft can be quite problematic for the pilot. If the plane lands on water, the most difficult thing is to achieve the desired pitch angle specified in the flight manual.

Also, during an emergency landing, the main (MLG) and auxiliary landing gear (nose landing gear, NLG) sometimes fail, this happens due to a malfunction of the mechanical or hydraulic propulsion system. With this failure, the landing gear either cannot fully extend from the housing in the fuselage or remains locked in the extended position. Airbag systems (AS) were proposed to increase safety in such situations. These ACs are activated before the impact of the aircraft, and reduce the impact load.

To solve this problem, the concept of an innovative safety and rescue system was created. The main purpose of this development is to reduce damage to the aircraft during an emergency landing, in addition, it is necessary to take care of the passengers of the aircraft. The reduction of damage depends on how high the speed and altitude of the aircraft were, and the angle of inclination during landing also plays a significant role. The basis of the concept is the use of airbags to facilitate the emergency landing of the aircraft. Regardless of the surface on which it will land, it is necessary to create the conditions for its most safe and effective landing.

To effectively use these airbags, you need to determine:

- their material, which must perform its task regardless of the landing place of the aircraft, whether it is land or water;
- their number, because only it will depend on how hard the emergency landing will be and the level of damage to the plane during landing, it also depends on the time the plane stays on the water;
- pressure, to find the load that the airbags can withstand, because the weight of the plane can reach hundreds of tons;
- location of airbags along the fuselage and wings of the aircraft;
- design and method of storage;

- size in assembled and activated state;
- the mechanism and conditions for activating the airbag launch system;
- a gas mixture for quick airbag inflation.

2.2 Choosing of the optimal method of airbags

An air bag system for aircraft of the auto-adaptive type, consisting of several rows of these bags, held under the fuselage and wings of the aircraft. Adapted to extend, when inflated after activation, from the underside of the fuselage and wings. Each airbag is configured for partial or full deployment for an alternate implementation of the first scheme. In the deployed form, the airbag body can extend the first length (H1) from the fuselage of the aircraft. And the second scheme, the airbag extends a second length (H2) greater than the first length (H1) from the fuselage of the aircraft. To determine the length and type of deployment (partial or full) of each airbag, action schemes are based on some parameters. These data are determined by the aircraft before the moment of contact with the ground or water surface.

A crash attenuation system for an aircraft, in which an airbag carried by the aircraft is inflatable on the exterior of the aircraft. The airbag has at least one vent for releasing gas from the interior of the airbag. A gas source is in communication with the interior of the airbag for inflating the airbag with the gas generated by the gas source. Airbag module with integrated gas generation that does not require a separate inflator or a separate filter. An airbag system for passenger air vehicles adapted to protect the aircraft from impacts. The airbag can at least partially surround the aircraft, enabling at least partial operability of the aircraft even after an impact. In some embodiments, the airbag could be inflated just before the aircraft makes contact with another object. The main limitation that known airbag systems have is the lack of an auto-adaptive capability that enables modifying the structure of the airbag based on the operating conditions, in particular, according to the pitch angle. The object of the present invention is to provide an airbag system for aircraft that overcomes the problems of the known art.[11]

The aforesaid object is achieved by the present invention, which relates to an auto-adaptive airbag system for aircraft of the type described earlier.

The invention will be explained with reference to the accompanying drawings, which show a non-limitative embodiment, in which:

• Figure 1 schematically shows an auto-adaptive airbag system for aircraft constructed according to a first embodiment of the present invention;

• Figures 2, 3 and 4 show the operation of the airbag system of Figure 1;

• Figure 5 schematically shows an auto-adaptive airbag system for aircraft constructed according to a second embodiment of the present invention:

• Figures 6, 7 and 8 show the operation of the airbag system of Figure 5;

• Figure 9 shows a detail of the airbag system according to the present invention; and

• Figure 10 shows the activation logic of the airbag system according to the present invention.

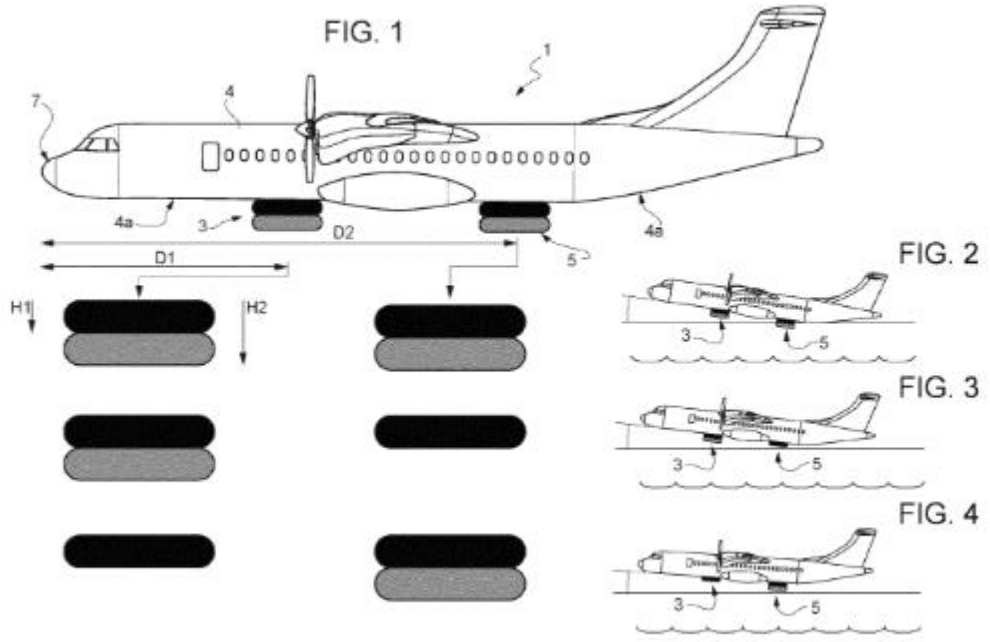


Fig. 1,2,3,4 Example of location airbags system

In Figure 1, reference numeral 1 indicates an airbag system for aircraft of an auto-adaptive type comprising a first group airbags assemblies 3 carried by the fuselage 4 of the aircraft and adapted to extend, when inflated following its activation, from a lower side 4a of the fuselage of the aircraft and at least a second group airbags assemblies 5 also carried by the fuselage 4 and adapted to extend, when inflated following its activation, also from the lower side 4a of the fuselage 4 of the aircraft. [11]

FIG. 5

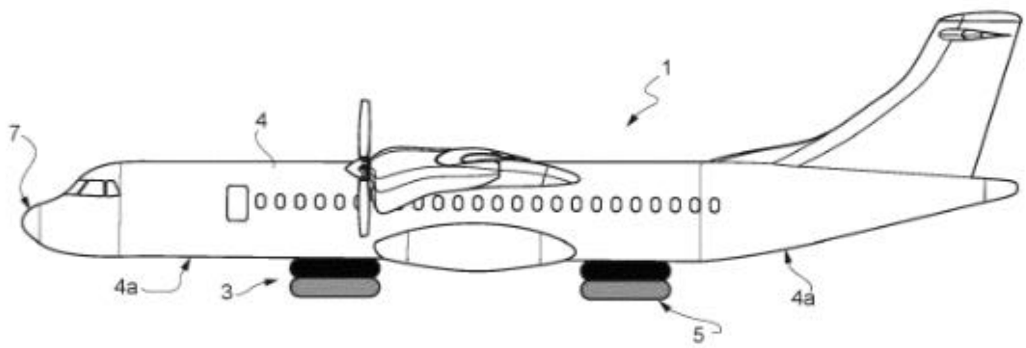


Fig. 5 Side view

The first and the second groups airbags assemblies 3, 5 are spaced from one another along the fuselage 4 of the aircraft. In greater detail, in the example of Figures 1-5, the first group airbags assemblies 3 of the front type (FWD) is at a shorter distance D1 from the front end portion 7 of the aircraft compared to the distance D2 at which the second group airbags assemblies 5 of the rear type (AFT) is from said front end portion 7. In this embodiment, the airbag assemblies 3 and 5 are aligned along a longitudinal direction of the aircraft and are used to reduce the loads applied to the fuselage 4 in the case of the aircraft making an emergency landing on a water surface. These aspects will be explained hereinafter. [11]

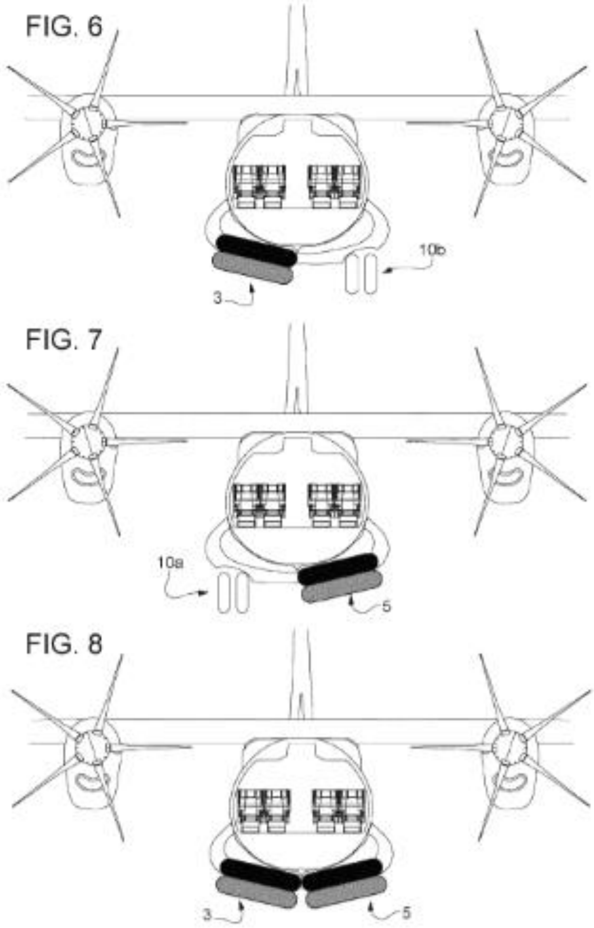


Fig. 6,7,8 Front view

In greater detail, in the example of Figures 5-8, the first group airbags assemblies 3 and the second group airbags assemblies 5 are arranged on opposite sides of the fuselage 4 near the housing of the right and left side main landing gears 10a, 10b (schematically shown) and are arranged on opposite sides with respect to the longitudinal axis of the aircraft to reduce the loads resulting from impact of the aircraft's fuselage with the ground in conditions of failure of one or both landing gears 10a, 10b. According to the present invention, each first and second groups airbags assemblies 3, 5 is configured to be partially or completely activated to alternatively carry out a first arrangement in which the airbag body extends by a first length H1 from the fuselage 4 of the aircraft and a second arrangement in which the airbag body extends by a second length H2 greater than the first length H1 from the fuselage 4 of the aircraft. In the example shown (see Figure 9), the first/second groups airbags assemblies 3, 5 comprises a first inflatable casing 12 configured to assume, when inflated in use, a toroidal shape about an axis 13 and a second inflatable casing 14 carried by the first casing 12 and configured to assume, when inflated in use, a cylindrical shape about the axis 13 with an elongated portion 16 extending axially through the central opening of the first toroidal inflatable casing 12. [11]

The first inflatable casing 12 is connected to at least one gas source 20 of the pyrotechnic type or any other type that ensures its equivalent rapid expansion adapted to create the appropriate pressure on the walls of the casing 12, situated in a specially provided, dedicated housing (kit) mounted entirely or partially on the outside of the fuselage 4 and the free end of the elongated portion 16 is connected to a gas source 22 with the same characteristics described above for the source 20. Both gas sources 20,22 are activatable by an electronic control unit 30. When only the first gas source 20 is activated, only the deployment of the first casing 12, which has an axial dimension close to H1, is carried out, when both gas sources 20 and 22 are activated, the deployment of both casings 12 and 14, which together have overall axial dimension H2, is carried out. Both casings 12 and 14 are fitted with respective valves 32, 33 that open when the pressure inside the casing 12, 14 exceeds a threshold value.[11]

FIG. 9

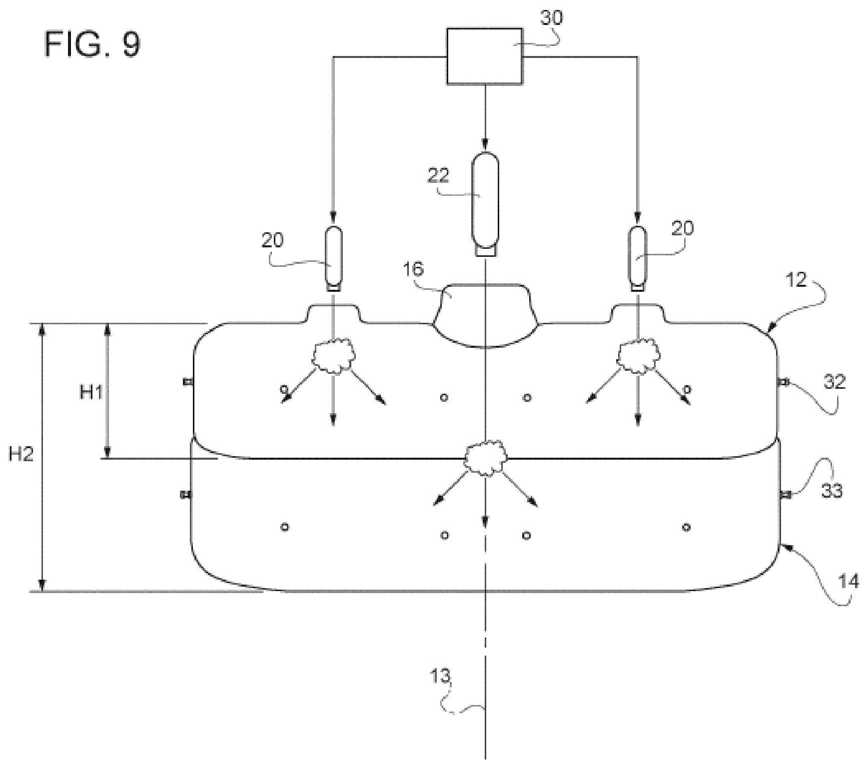


Fig. 9 Airbag activation system

The longitudinal distance L between the first groups airbags assemblies 3 and the second group airbags assemblies 5 is defined according to the maximum correction ΔθMAX of the pitch angle upon impact, based on the relation:

$$\Delta\theta_{MAX} = arctang\ (t2/L)$$

where L is the longitudinal distance and t2 is the axial dimension of the second inflated casing 14. As will be explained in detail hereinafter, the electronic control unit 30 is adapted to detect aircraft parameters prior to impact with the water surface or the ground in order to carry out the partial/total activation of each first/second groups airbags assemblies 3, 5 and reduce the impact loads. The operation of the electronic control unit 30 is described in the flowchart of Figure 10. Following activation of the system (block 100), the operator can choose (also through a manual selector) activation of the airbag system 1 in an emergency water landing mode (block 110, Ditching Mode) and a landing mode on the ground with failure of one or both main landing gears (block 120, Crash Mode). In the first case, block 110 is followed by block 130, which proceeds with reading of the height H_{oe} of the aircraft via the flight instruments (altimeter). When the height Hoe is above an activation value $H_{oe\text{-}lim}$, the system remains in a loop (block 140 is followed by block 130), otherwise block 140 is followed by block 150, which proceeds with reading of the aircraft's pitch angle. This data is also available from the flight instruments.[11]

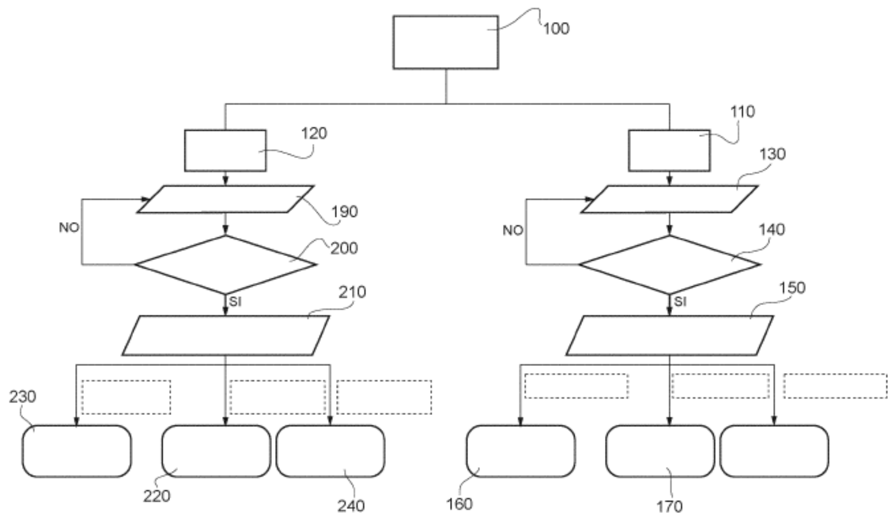


FIG. 10

Fig. 10 Flowchart of the activation logic of the airbag system

Based on the data detected in block 150, the electronic control unit 30 is adapted to control:

- the total activation of the first group airbags assemblies 3 and the second group airbags assemblies 5 when the measured pitch angle is equal to or very close to, according to a prescribed tolerance, a target pitch angle envisaged in the flight manuals to reduce impact loads (block 160, Figure 2). For example, the above-described situation occurs when the measured pitch angle (in sexagesimal degrees) is simultaneously greater than or equal to the target pitch angle (in sexagesimal degrees) decreased by 1 sexagesimal degree (prescribed tolerance) and less than or equal to the target pitch angle (in sexagesimal degrees) increased by 1 sexagesimal degree (prescribed tolerance);

- the total activation of the first group airbags assemblies 3 and the partial activation of the second group airbags assemblies 5 when the measured pitch angle is greater than the target pitch angle beyond a prescribed tolerance (block 170, Figure 3). For example, the abovedescribed situation occurs when the measured pitch angle (in sexagesimal degrees) is greater than the target pitch angle (in sexagesimal degrees) increased by 1 sexagesimal degree (prescribed tolerance);

- the partial activation of the first group airbags assemblies 3 and the total activation of the second group airbags assemblies 5 when the measured pitch angle is less than the target pitch angle beyond a prescribed tolerance (block 180, Figure 4). For example, the above-described situation occurs when the measured pitch angle (in sexagesimal degrees) is less than the target pitch angle (in sexagesimal degrees) decreased by 1 sexagesimal degree (prescribed tolerance).

The above-described operations contribute to modifying, upon impact with the water surface, the first point of the aircraft (i.e., the first or second groups airbags assemblies 3, 5) that makes contact with the water by correcting, at least partially, the pitch angle upon impact, to make it as close to the target angle as possible. [11]

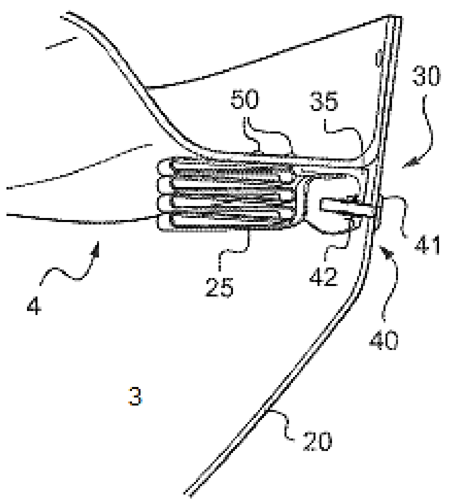


Fig. 11 An example of the location of the prototype in the fuselage

Block 120 is followed by block 190, which proceeds with reading the height H_{oe} of the aircraft via the flight instruments (altimeter). When the height H_{oe} is above an activation value $H_{oe\text{-}lim}$, the system remains in a loop (block 200 is followed by block 190), otherwise block 200 is followed by block 210, which proceeds with reading the operational or failure state of main landing gears of the aircraft. This data is also available from the flight instruments:

- when both main landing gears are in a state of nonextension or unlocked extension, full activation of the first and second groups airbags assemblies 3, 5 is triggered (block 220, Figure 7);

- when the right main landing gear 10a is in a state of non-extension or unlocked extension, activation of the airbags assemblies 3 arranged near the housing of that landing gear is triggered (block 230, Figure 6); and

- when the left main landing gear 10b is in a state of non-extension or unlocked extension, activation of the airbag assembly 5 arranged near the housing of that landing gear is triggered (block 240, Figure 8).[11]

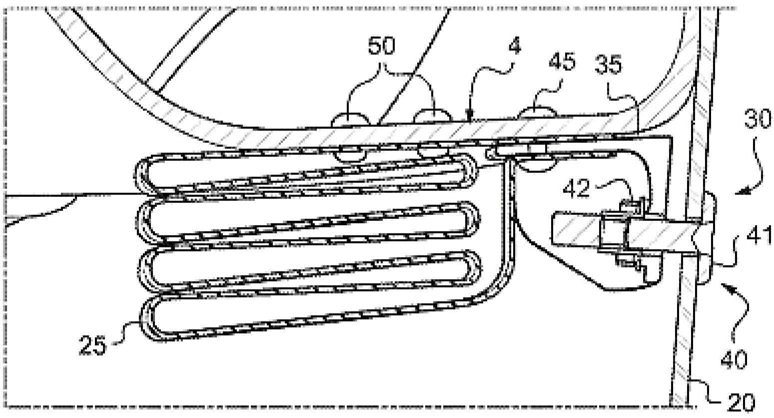


Fig. 22 Prototype of an airbag in folded form

In this way, the electronic control unit 30 controls the activation of the first and/or second groups airbags assemblies 3, 5 next to the landing gear(s) in the failure state. The above-described operations contribute to mitigating the effects of the crash due to the partial or total lack of landing gear with the activation of the airbag assemblies 3, 5 on one or both sides of the fuselage.

The described system can be easily installed on an existing aircraft without substantial changes to the design of the fuselage. The system can thus be configured as a specific aircraft improvement kit, permitting the system to be offered as a retrofit for aircrafts already in service.[11]

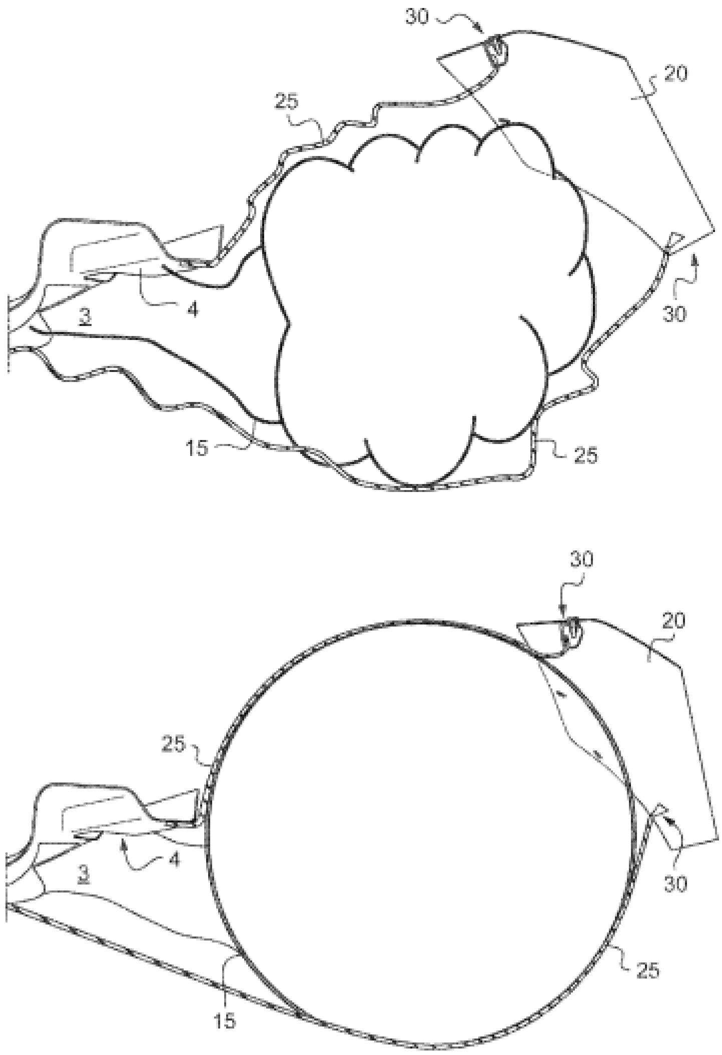


Fig. 13 Prototype airbag in partial/total activation

2.3 Calculation of the use of airbags

2.3.1 Project part of the airbag

An airbag is an aircraft device designed to withstand loads during an emergency landing. The device consists of the pillow itself, an air valve, a pyro cartridge with a gas cylinder of a certain capacity, a fuselage plug, launchers, height and flight angle sensors, and a limiting rope.

Hypalon will be used for the main material of the airbag. Its brief description and characteristics are described below:

Hypalon (CSM) is a premium-grade synthetic rubber manufactured from chlorosulfonated polyethylene (CSPE). Hypalon is chemical and flame resistant, handles temperature extremes and is resistant to ultraviolet light and abrasion. It’s waterproof and extremely durable, making it suitable for many applications.[12]

Properties:

- Resistant to alkalis and acids
- Color stability
- Resistant to temperature extremes
- Weather and ultraviolet light resistant
- Smooth material forms to different applications
- Excellent adhesion to metals
- Good electrical properties
- Radar transparent

Physical properties:

- Elongation: 100% – 800%
- Hardness Range (Durometer Shore A): 45 – 95
- Tensile Strength: 1,000 – 3,000psi

Thermal properties:

- Minimum Service Temperature: -60º F
- Maximum Service Temperature: 275º F

For effective use, it is necessary to know the total number and diameter of airbags required for use on the prototype aircraft, i.e.Airbus A380:

$$D_{ab} = 2 \text{ m}$$

For this aircraft, it was decided to take 32 airbags for effective distribution of loads during landing;

$$k_{ab} = 32$$

The pressure of airbags will be equal 500 kPa, it was determined by the method of selecting optimal data. After all, when the airbags are activated, they will have to absorb the entire impact during an emergency landing:

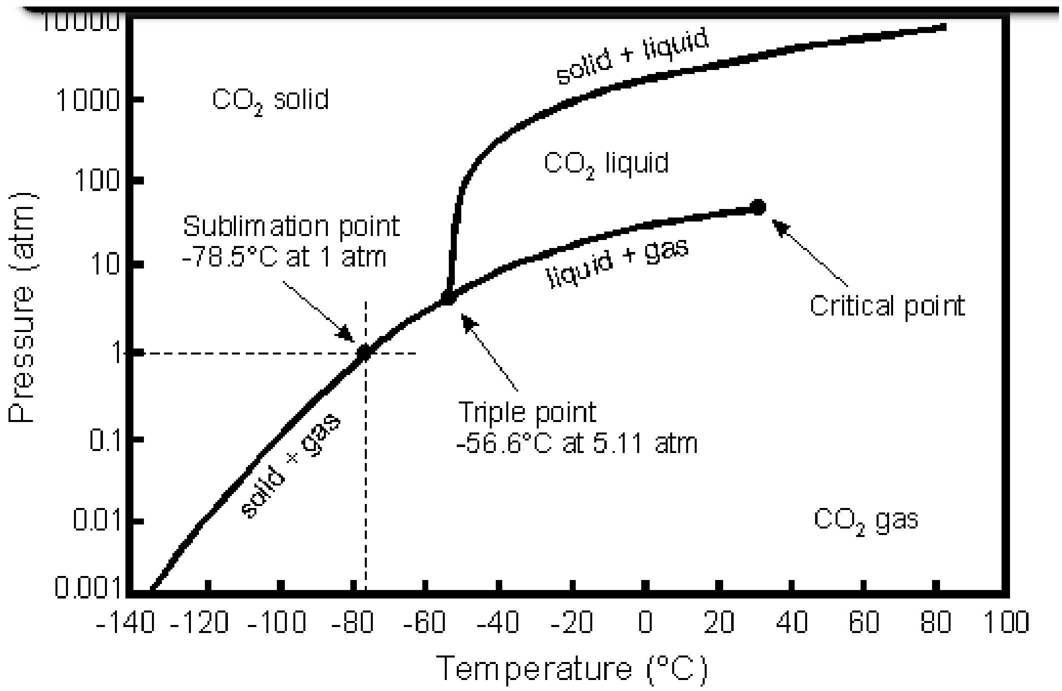
$$P_{ab} = 500 \text{ kPa}$$

It is also known that the material of the airbag can withstand high loads, that is, this internal pressure is optimal for the airbag.

The gas activated together with the pyro cartridge is carbon dioxide:

$$\rho_{gas} = 1.97\ kg/m^3$$

The location of the airbags will be along the entire fuselage of the aircraft.



Pressure-Temperature phase diagram for CO_2.

2.3.2 Ditching on the water

2.3.3 Landing on the ground

To find the overload in an emergency situation, we first find the impact force of the plane on the ground:

$$F = n \cdot m \cdot g$$

$$F = 5 \cdot 365508 \cdot 9.8 = 17909892\ \text{N}$$

, where n - is the overload coefficient of the aircraft along the y axis.

It is known that the pressure of the airbag upon activation, but upon impact from landing, the pressure changes:

$$S = \frac{k_{ab} \cdot \pi \cdot D^2}{4}$$

$$P_{gr} = \frac{F}{S} = \frac{4 \cdot n \cdot m \cdot g}{k_{ab} \cdot \pi \cdot D^2}$$

$$P_{gr} = \frac{4 \cdot 5 \cdot 365508 \cdot 9.8}{32 \cdot 3.14 \cdot 2^2} = 178243.352 \text{ Pa} = 0.178 \text{ mPa}$$

Full pressure of one airbag during landing impact:

$$P_{full} = 500 + 178 = 678 \text{ mPa}$$

The full pressure of the pillow does not go beyond the maximum capabilities(about 21278 mPa).

Now let's calculate the gas work of the balls, how much the impact force will change with them and the efficiency of all the balls when landing:

$$A = \frac{P_{ab} \cdot V_{ab}}{k-1} \cdot [(\frac{P_{full}}{P_{ab}})^{\frac{k-1}{k}} - 1]$$

$$A = \frac{500000 \cdot 4.19}{0.4} \cdot \left[\left(\frac{678000}{500000}\right)^{\frac{0.4}{1.4}} - 1\right] = 475998 \text{ J}$$

$$A = F \cdot h = F \cdot D$$

$$F_{ab} = \frac{A}{D} = \frac{475998}{2} = 237999 \text{ N}$$

Final impact force with an airbag:

$$F_{fi} = F - F_{ab} \cdot k_{ab}$$

$$F_{fi} = 17909892 - 237999 \cdot 32 = 10296032 \text{ N}$$

The airbag load reduction factor is equal to:

$$n_{ab} = \frac{F_{fi}}{m \cdot g} = \frac{10296032}{365508 \cdot 9.8} = 2.874$$

The difference in load factors:

$$\frac{n_{ab}}{n}$$

$$\frac{2.874}{5} = 0.5748$$

That is, due to the use of airbags, there is a reduction in the load when hitting an airplane, i.e. airbags can absorb up to 42.7% of the entire impact.

Conclusion of special part

The main calculate equation and design of airbags were determined in this part.

When choosing the right type of airbag, many factors were taken into account, such as the efficiency of using this device and the ability to install it without affecting the operation of the aircraft's fuselage. An important role was played by the fact that Hypalon has excellent load characteristics, thereby allowing this analysis to be made.

It is also assumed the simultaneous use of first and second groups of airbags assemblies at once. Calculations were carried out in different landing conditions (on different surfaces) in order to have a deeper understanding of the operation of airbags and whether they are actually effective.

After calculating the loads, it is possible to conclude that the airbag has fully proven its effectiveness during landing.

3. Environmental protection

3.1 Introduction

Activities related to the creation and use of aviation equipment are one of the most important areas of application of intellectual and technical capabilities and components of scientific and technical progress. However, along with positive consequences, there are also negative ones, namely pollution of the natural environment, reduction of raw and energy resources, negative impact on human health, etc. Air transport is one of the main polluters of atmospheric air, water resources and soil, although it is 15% inferior to road transport. The problem of disposal and processing of waste arising during the operation of aircraft and after the end of their service life is acute. Among them, air pollution causes the greatest damage to the environment.[13]

The share of air transport in the total volume of emissions of harmful substances into the atmosphere is 17%.

The goal in the field of ensuring environmental and technogenic safety of air transportation and the functioning of aviation complexes is:

- maintenance of an ecologically safe environment favorable for health;
- ensuring rational nature management;
- balance of processes of reproduction and use of renewable and non-renewable natural resources;
- preservation of the genetic fund, species and landscape diversity of flora and fauna.

Also, the level of pollution depends on the type of aircraft. Usually, a cargo plane consumes more fuel and emits more exhaust gases than a passenger plane.

Experts believe that the increase in environmental protection problems is directly related to the growth of civil aviation, that is, the increase in the use of airplanes. Aircraft engines especially affect the climate, due to the emission of carbon dioxide and nitrogen oxide, water and methane. The chemical and radiation level of the atmosphere changes, and soot sulfate aerosols are also emitted.

3.2 Impact of aircraft on the natural environment and atmosphere

The increase in the volume of air transport, the intensity of the processes of operation and repair of aircraft causes an increase in pollution. The impact of transport on the ecosystem is:

- in the pollution of the atmosphere, water bodies and lands, changes in the chemical composition of the soil and microflora, creation of industrial waste, including radioactive and toxic, ash and garbage. Pollutants have a negative impact not only on anthropogenic, but also on natural systems.

- in the use of natural resources - atmospheric air (necessary for working processes in internal combustion engines), petroleum products and natural gas, water (used for cooling internal combustion engines, washing vehicles) and land resources (necessary for the construction of airports, runways, etc.) ;

- in the release of heat into the environment;

- in creating a high level of noise and vibration;

- in the possibility of creating negative natural processes, such as erosion, waterlogging of the area, landslides, landslips;

- in injury and death of people, death of animals in accidents and catastrophes;

- in the destruction of the soil and plant cover and the reduction of the yield of agricultural crops.

Airplane flight pollutes the environment with exhaust gases. A huge amount of carbon dioxide and water vapor, nitrogen oxide and soot enters the atmosphere through airplanes. The amount of exposure to these components depends on the altitude of the aircraft. Any human economic activity causes some damage to nature and changes the climate. It is only necessary to understand how much influence its activities have on the pollution of nature.[14]

3.3 Types of atmospheric pollution

Aviation fuel (kerosene) is a complex mixture of hydrocarbons. Carbon makes up 86 percent of it, hydrogen - 14 percent. When burning kerosene, carbon combines with oxygen. Therefore, when an airplane consumes one kilogram of kerosene, 3.15 kilograms of carbon dioxide enters the atmosphere. Carbon dioxide is evenly distributed around the entire globe. But in addition, this substance can also spread vertically, so usually a large amount of it is formed at an altitude of 10-11 thousand meters. Airplanes emit about 2.2

percent of all anthropogenic carbon dioxide into the atmosphere.[15]

It is much more difficult to estimate the impact of water vapor produced by aviation. Burning one kilogram of kerosene produces 1.23 kilograms of water vapor. The steam condenses in the cold environment due to the hot and humid exhaust gases from the engines. Small water droplets form at low altitudes, and small icicles form at high altitudes, due to the fact that the air temperature outside is 30-50 degrees below zero. These droplets and icicles are sometimes clearly visible from the ground - in the form of a so-called condensation trail that follows the plane. The effect of this condensation trail on the atmosphere also depends on the altitude.

The ice sheets of the condensation trail in the startosphere quickly evaporate, because the moisture content in it is very small, no more than 0.01 ppm. But in the troposphere, where the air masses are extremely saturated with moisture, the behavior of the condensation trail depends on many weather factors. At high air humidity, ice crystals absorb additional water, grow and, together with the condensation trail, can form cirrus clouds. Due to the promotion of condensation of moisture from the air, the density and water content of clouds increase.

Also, exhaust gases from aircraft engines affect the concentration of ozone in the atmosphere. In a modern engine, the temperature of the combustion chamber can reach 2000 degrees. At this temperature in the atmosphere, nitrogen combines with oxygen and forms oxides NO and NO_2. These oxides affect atmospheric ozone in different ways, it depends on the altitude, at high altitudes they decompose it, at low altitudes - they form it.[16]

Cloud cover in the form of linear condensation trails and cirrus clouds increases due to aerosols and their precursors (soot and sulfate). These traces can exist for several minutes or hours, depending on the state of the surrounding atmosphere. They can spread several kilometers wide, resembling cirrus clouds. The radiation balance depends on the emissions of soot particles, because solid products that play the role of condensation nuclei are formed during incomplete combustion of fuel. In the upper troposphere, soot particles have a size of 0.1-0.5 microns and consist of agglomerates of primary aerosols with a diameter of 20-40 nm. The average concentration of these particles can vary from 0.004

to 0.5 cm-3. To assess the effects of the emission of soot aerosols on the atmosphere, the main attention was paid to the change in the composition of the atmosphere, due to heterogeneous chemical reactions on the surface of soot particles. But the influence of the emission of these particles on the gaseous composition of the atmosphere was not detected.[17]

At an altitude of 16,000 meters, ozone decomposition is exceeded, but ordinary civilian aircraft do not reach such a height. Usually their flight height does not exceed 12 thousand meters. At such an altitude, nitrogen oxides cause the active formation of ozone. Unfortunately, this tropospheric ozone, like carbon dioxide or water vapor, increases the greenhouse effect. Also, the increased content of ozone in the air has a negative impact on health. Tropospheric ozone is in no way related to the ozone layer in the stratosphere, it does not protect our planet from harsh ultraviolet radiation. That's why you can't patch the ozone hole over Antarctica with airplane exhaust. [16]

3.4 Structural and technical measures to reduce environmental pollution

Measures to reduce atmospheric air pollution:[18]

- increasing the efficiency of engines, which is achieved by improving their design;
- reducing the weight of the structure due to the use of composite materials;
- reduction of movement resistance, which is achieved by the well-thought-out aerodynamic shape of the aircraft;
- reducing the toxicity of exhaust gases, which is achieved by installing filters and using fuel additives;
- use of environmentally cleaner types of fuel;
- improvement of the technological process and bringing it to "waste-free" production;
- cleaning of ventilation and technological emissions; o wider use of electricity.

Noise and vibration reduction measures:

- creation of less noisy power plants;
- use of more advanced air intakes;
- use of vibration, sound-absorbing and protective screens and hoods;
- sealing of equipment and communications;

- dispersion of noise sources on the territory of the airfield;
- the use of stationary and mobile silencers when testing engines on the ground;
- execution of special take-off and landing methods, such as the use of "low throttle" when taxiing, steeper take-off and landing trajectories, etc.

3.5 Calculation of aircraft engine emissions

Emission sources associated with aviation can spread and lead to deterioration of air quality in nearby settlements. These emissions represent a potential risk to public health and the environment, as they can cause an increase in surface ozone concentration and lead to acid rain. National and international air quality monitoring programs constantly require authorized aviation and government organizations to monitor air quality near airports.

Over the past few decades, significant progress has been made in reducing emissions due to the improvement of the environmental friendliness of aviation fuels (partial replacement of kerosene with liquefied natural gas or biofuel) and technical improvements in aircraft engines (increasing their traction efficiency, which implies a reduction in fuel consumption).

The quantitative characteristic of emissions of harmful substances by aircraft engines is the emission index EI, which shows how many grams of harmful substances are emitted into the air when burning 1 kg of fuel [19].

EI characterizes the quality of the organization of the combustion process in the combustion chamber of each engine model and is therefore related to the design and operational characteristics of the combustion chamber.

The content of CO and C_XH_Y ingredients is due to incomplete combustion of fuel in the engine, and this process depends on the value of the combustion coefficient η and the engine operating mode. The maximum completeness of fuel combustion occurs in the take-off mode (thrust - maximum, η=0.9-0.99). In all other modes, η=0.75...0.85. The NO_X content in the exhaust gases depends on the temperature of the mixture in the combustion chamber (the higher the temperature, the more NO_X is released) and the time the mixture stays in the combustion chamber (the longer the mixture is in the chamber, the more NO_X).

In 1 year, a modern airliner performs up to 300 takeoffs and landings. At the same time, the engines emit approximately 3.5 t of CO, 2 t of C_XH_Y, and 1.7 t of NO_X per day. The share of atmospheric air pollution with hydrocarbons in airports is about 20%.

In connection with these statistics, there was a need to limit emissions from aircraft engines, therefore the International Civil Aviation Organization (ICAO) developed standards for the amount of emissions of the following harmful substances:

- carbon monoxide (CO);
- unburned hydrocarbon compounds (C_XH_Y);
- nitrogen oxides (NO_X);
- smoke number (SN).

The IKAO standards for the emission control parameter for mainline aircraft, the thrust of which exceeds 27kN are as follows:

$M_{CO}/R_0 \leq 118$ g/kN;

$M_{CxHy}/R_0 \leq 19{,}6$ g/kN;

$M_{NOx}/R_0 \leq 80$ g/kN;

$SN \leq 10$,

where M_i is the mass of the ejected harmful substance for a certain time of engine operation (in grams), R_0 is the take-off thrust of the engine (in kN).

3.6 Conclusion

Air transport is a relatively clean form of transport, but it still has an impact on the climate and the environment. Therefore, the growing demand for air traffic can lead to an increase in pollution in the troposphere. The International Civil Aviation Organization is trying to reduce the negative impact on the environment. For this, new standards are being developed to reduce aviation noise and emissions of harmful substances. The requirements for aircraft in operation are being strengthened, and the list of aviation emissions that certify aircraft engines is expanding. The ICAO committee proposes a Global Market Action Mechanism as the main instrument for regulating the negative impact of aviation on the atmosphere, although not all ICAO members support this idea. There is a clear need to introduce new technologies in the aviation industry to reduce the environmental impact of air transport.

4. Labor protection

4.1 Introduction

During operation and repair of the system, a person may be affected by one or a number of dangerous and harmful production factors, which are outlined in the following documents: USS EN 1915-1:2013. Aviation ground equipment. General requirements. Part 1. Basic safety requirements, 1915-2:2013. Aviation ground equipment. General requirements. Part 2. Requirements for stability and strength, methods of calculation and testing and GOST 12.0.003-2015 "OSS. Dangerous and harmful production factors. Classification". Safety measures during maintenance and repair are regulated by: state and industry standards; systems of labor safety standards, technical operation and repair of aviation equipment; maintenance regulations; repair technology, manuals and instructions on labor safety, etc. Also, the levels of dangerous and harmful production factors should not exceed the maximum permissible values established in sanitary norms, rules and regulatory and technical documentation.

There are different types of processes during the production and manufacture of the aircraft body and skin, such as the preparation process, the equipment manufacturing process, the workpiece preparation process, the detailing process, the assembly and testing process. During the manufacture of the aircraft, there are consistent technologies that differ from general mechanical production (such as a model mold line), and there is also a large amount of unique process equipment (such as mold tires, frames and various fixtures and fittings, etc.). These technologies and equipment usually act as insurance for the enterprise. The manufactured plane has a clear shape. The preparation process includes the determination of coordination methods and coordination routes in the process of production and design of technological equipment.[20]

4.2 Analysis of labor conditions in the workplace

1 Aircraft fuselage skin processing workshop

There are many types of equipment in the fuselage skinning workshop. During the construction of the aircraft, the air will be mixed with the strong smell of paint from chemical products or from the operation of various drilling and welding machines, so air ventilation is necessary at all times. Technicians in the workshop need qualified skills to work, they also have certain requirements for physical training, because the intensity of work in production is relatively high.[21]

There are also some dress code rules:

- when choosing overalls and other means of personal protection, you should pay attention to whether it meets the conditions at the workplace, the degree of existing risks to the life and health of employees and does not lead to an increase in the level of this risk, and whether it suits the user after the necessary adjustment ;
- a means of protection intended to protect the user simultaneously from several types of danger must meet the basic requirements for means of protection against each type of danger;
- overalls and PPE arriving at the enterprise must be checked for compliance with state standards and regulatory documents;
- the color of work clothes must be uniform;
- special clothing must meet strict manufacturing requirements and have appropriate technical characteristics regarding protective properties.
- workers working on some processes must wear protective glasses and masks.

There are hundreds of processes for an aircraft fuselage. This is a very large project, so the manufacture of the plane takes hundreds of hours. To check the products, workers must carry out thorough checks step by step, and no one can be missed. The potential safety hazards are countless. Most of the current safety rules and regulations are based on accumulated experience, such as previous injuries or sacrifices of the predecessors.[22]

CNC machining workshop

CNC machining workshops are filled with a variety of large-scale machines, such as planers, lathes, milling machines. All equipment of an aircraft manufacturing plant is super-large machinery, than that similar equipment of ordinary workshops. These large-sized machines are not only in automatically operation, but also with the workers. All of this factors will create a safety hazard during the manufacturing and maintenance process.

Sheet metal processing workshop

There are still a lot of manual processing in domestic sheet metal processing workshops now, especially fitters. This workshops have a high demand for qualified skilled workers with safety awareness.

During the operation, maintenance or installation of the rescue system, the worker may be exposed to the following dangerous and harmful production factors:

• moving machines and mechanisms; unprotected moving elements of production equipment; moving products, blanks, materials;

• collapsible structures (stairs, ladders, etc.);

• increased dustiness and gassiness of the air;

• increased or decreased temperature of the surfaces of machinery, equipment, materials;

• increased sliding (due to icing, moisture or oiling of surfaces on which personnel move);

• increased or decreased temperature, humidity and air mobility;

• increased level of static electricity;

• the location of the workplace (work zone) at a height relative to the surface (floor);

• absence or lack of natural light;

• insufficient lighting of the working area;

• chemically dangerous and harmful substances.

4.3 Labor protection measures:

1. The main goal of labor protection regulations is the safety of workers. For the safety of workers, it is necessary to reduce the probability and number of accidents, i.e. the introduction of compulsory labor protection measures and protective equipment for workers during work at aviation assembly workshops, reducing the impact of dangerous and harmful production factors in order to prevent safety accidents caused by accidents during work. Reducing injury accidents can also minimize occurrence of machine failure incidents (breakdowns).[21]

2. Before starting work officially in the workshop, a new employee must complete factory safety and operational skills training and pass a final assessment. Also, every

year, previous(regular) workers in the workshop are obliged to participate in various trainings on safety techniques, with the aim of constantly updating knowledge on safety techniques, in order to reduce the number of accidents.

3. Workshop operators must strictly follow the established work procedures of their respective workshops, for example they must wear protective clothing in addition to tools: work shoes, protective headgear, gloves, safety shields, safety glasses and ear plugs. Only after completing these formalities and protective measures is it possible to work during operation or overhaul in hazardous areas.

4. Sick employees have the right to take sick leave. It is allowed to take sick leave only for treatment or recovery, provided that the employee fell ill or was injured outside of work (not related to work). Usually, an employee has the right to take 12 days of paid vacation at the expense of the company per year. If the treatment will take longer than 12 days, the excess time may be treated as personal leave with the special permission of the CEO.

5. Employees have the opportunity to take leave if they are injured at work. Wages will be paid as hospital benefits in connection with the injury. Usually, medical expenses and other services are paid by the insurance company. If a worker injured at work requires care during the period of treatment, the company will send someone to care for him, but only after confirmation from the worker's company.[21]

6. In order not to cause or reduce safety accidents due to the use of alcohol, all employees in the workshop are prohibited from consuming alcohol eight hours before starting work.

7. Employees are not allowed to work two consecutive shifts to avoid safety accidents or injuries caused by excessive fatigue.

4.4 Fire safety education and training system:

1. Pre-training on fire safety is mandatory for all new workers at the factory. The training content includes: basic knowledge of fire safety, operation and use of fire extinguishers and hydrants, etc.

2. Fire safety training is conducted for every regular employee, but at least once a

year. During the training, the assessment and behavior of the employee is recorded in the safety register.

3. Every working quarter, the company conducts evacuation training for all employees. Volunteer firefighters are also invited to conduct special training on firefighting at the workplace. With the help of such measures, each employee acquires certain skills and behavior in the event of a fire.

4. At every production, there are persons responsible for fire safety, such as the head of fire safety, full-time and part-time fire protection personnel, fire control room operators and others. Everyone responsible for fire safety undergoes special fire safety training.

5. All employees who work in fire-hazardous premises and operators of automatic fire extinguishing systems must undergo fire-fighting training and have relevant certificates. Fire-hazardous premises include: electric welding, gas welding, boiler rooms and others.

6. Education and training on fire safety depends on the type of workshop, brigade or other department and is based on their individual characteristics and stage of work.

7. The plant must conduct regular safety publicity and fire safety education in various forms.

4.5 Fire protection inspection system:

1. For the enterprises, it is necessary to form a gradual system of responsibility for fire safety and a system of responsibility for fire safety after a fire, clarify their respective duties and introduce an inspection system.

2. The safety department, together with the environmental safety department, should conduct daily inspections of fire protection systems at the factory, monthly inspections to predict fires and further improve fire protection systems.

3. If a fire hazard is detected during the inspection, the inspector must fill out a report and, in accordance with regulations, require the relevant personnel to sign the report.

4. The inspection unit immediately notifies the inspected unit in writing form about the results of the inspection, and the head of the inspected unit promptly eliminates fire hazards in accordance with the requirements of the notification.

5. If the hidden fire hazard discovered during the inspection is not eliminated in a timely manner within the set period, it is punished in accordance with the company's regulatory acts.

4.6 Safety evacuation facility management system:

1. The Safety Department of the plant independently sets the width of the doors of escape exits, evacuation corridors and stairs, warehouses and dormitories on the territory of plant. All these parameters are adjusted according to the technical specifications at the factory..

2. Emergency lighting and evacuation signs must be on all escape exits, stairs and walkways.

3. All safety exits must be open. Therefore, when starting work, it is necessary to check each exit in the workshop or warehouse.

4. In workshops and warehouses, it is necessary to follow the rules for storing items and not to obstruct the safety exits or escape corridors with the same items.

5. The responsible person of each unit must regularly check the serviceability of escape signs and emergency lighting in accordance to this regulations and repair them in case of damage.

4.7 Maintenance and management system for fire-fighting facilities and equipment:

1. The fire safety department manages all fire fighting facilities and equipment in the company. Also, this department regularly checks and tests this equipment for operability.

2. Establish file management of availability archive for fire-fighting facilities and fire-fighting equipment .

3. All fire-fighting facilities and equipment must be stored in specially designated places at the factory. There should also be specially assigned personnel for regular inspection and recording of their status in the archive.

4. There are also duties that all company employees must comply with. The employee must take proper care of the fire extinguishing facilities and equipment. The company has the right to demand compensation from violators in case of intentional destruc-

tion or damage of fire extinguishing means and equipment.

5. It is the company's duty to install and maintain in good condition fire-fighting escape signs, emergency lighting and other fire-fighting equipment, in accordance with the current requirements of national legislation. Also, these facilities must comply with the national norms of the relevant legislation.

4.8 Fire hazard rectification system:

1. Fire inspections of all production departments are carried out every month. Usually, this is done by the functional department of security service management, and this department also monitors both their detection and on-the-spot elimination of these violations in advance.

2. Every month, the fire safety department holds a meeting to discuss the conclusion of the fire safety inspection. In this way, all hidden fire hazards are discussed, which are identified during the inspection, their immediate elimination and ensuring further safe production.

3. All departments of the company shall promptly urge relevant personnel to implement rectification measures after receiving the rectification of fire hazards at the same time. Departments that cannot be rectified for a while shall implement preventive measures to ensure fire safety.

4. Appropriate personnel, i.e. fire safety, must immediately eliminate the fire hazard upon receiving notification of a fire hazard. If another department of the company detects a danger, they should immediately notify the relevant personnel and act according to the evacuation and fire fighting instructions. Prevention of fire safety must be ensured even in that unit, which will not even be subject to repair or restoration of work for a while.

5. The department or the person responsible for eliminating the fire hazard, after completing its elimination, must report the current situation to the company's fire safety. After checking and signing the report, it is filed in the archive for further use in the formulation of new fire safety measures.

4.9 Fire safety management:

1. It is necessary to observe safety rules when working with hot fire and similar

tools. When hot work is required, the responsible unit applies, in accordance with regulations, for a permit to the safety department and other regulatory departments, such as the fire safety department. The division that issues the contract submits an application for construction outsourcing.

2. To prevent fire hazards, when performing some operations, all flammable and explosive objects must be removed within four and a half meters from the hot spot, or isolated according to fire safety rules. Also, during such operations, all fire-fighting equipment must be ready at any time. Additional firefighting equipment is usually borrowed from the fire department and must be returned to them immediately. In the case of forced use, a report must be submitted, but in the case of intentional use, all losses will be compensated by the unit responsible for this act.

3. The head of the manager level of the unit in which the construction is carried out in accordance with regulatory documents is responsible for conducting hot construction. Also, the responsible unit must organize, together with the fire safety department, direct supervision of safety at the facility. A separate person must monitor, ensure safety and keep full responsible if hot work is carried out at a height of more than 2 meters. With such types of work, objects can easily catch fire at any time from the sparks of the tools.

4. When submitting an application for hot work, night fires are prohibited, that is, provided that the safety of normal production and the absence of the influence of night fires will be ensured. Monitoring of night fires is especially important when working in dangerous work areas, such as flammable and explosive objects.

5. Overtime hot work during holidays or non-working days is carried out only with prior agreement and signature of the application by the relevant departments. Such requests should be submitted well in advance, especially before the holidays, as the responsible department must send personnel to monitor security. If the respondent is conducting hot work, the contracting department will send a person to supervise.

6. If hot work is carried out without the appropriate permission, the department responsible for this act will receive repeated punishment or dismissal of personnel under special conditions. If the department responsible for the violation is hired by an outside contractor, they must pay the appropriate penalties for the violation. Construction will be

resumed only after payment of the fine, submission of the appropriate application and completion of legal formalities.

4.10 Conclusion

The main goal of labor protection is to protect the health of workers. Health and safety care exists to minimize risks, especially during aircraft maintenance. In the section "Occupational safety" there is a list of dangerous and harmful factors during the maintenance and operation of aircraft systems. Also, during the labor process, workers have a risk of poisoning by harmful substances. Therefore, one of the priority measures in production is the early prevention and elimination of the leakage of harmful substances during maintenance. In order to effectively protect the health of employees, every enterprise must meet occupational hygiene standards.

A significant role in labor protection is played by fire and explosion safety during maintenance of aircraft systems. All fire and explosion safety work of enterprises is carried out in accordance with the regulations on fire protection of enterprises, organizations and institutions of civil aviation. These measures provide for the prevention of fire and explosive situations.

General conclusions and recommendations

During this designing work I’ve got the next results:

- preliminary design of the long-range aircraft with 550 passengers;
- the schematic design of the layout of the long-range aircraft with 550 passengers;
- the center of gravity of the airplane calculations;
- the calculation of efficiency analysis of using the airbags;
- the design of airbags.

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

A new device for safe and rescue during emergency landing, which has no analogues in efficiency, has been proposed. This will reduce the number of injured passengers and damaged aircraft, regardless of the landing surface.

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APPENDIX