МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет аеронавігації, електроніки та телекомунікацій

Кафедра авіаційних комп’ютерно-інтегрованих комплексів

ДОПУСТИТИ ДО ЗАХИСТУ

Завідувач випускової кафедри

_______Віктор СИНЄГЛАЗОВ

“_____”_____________2023 р.

КВАЛІФІКАЦІЙНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ

“МАГІСТР”

Спеціальність 151 “Автоматизація та комп'ютерно-інтегровані технології ”

Освітньо-професійна програма “ Інформаційне забезпечення та інженерія авіаційних комп’ютерних систем”

Тема: Система оцінки залишку пального при затримці посадки

Виконавець: студент групи ІЗ-225Ма Нікулін Артем Іванович

Керівник: кандидат технічних наук, доцент Смірнов Олег Ігорович

Консультант розділу «Охорона навколишнього середовища»____Радомська М.М.

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Нормоконтролер:__________Філяшкін М.К

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Київ – 2023

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

Faculty of Aeronautics, Electronics and Telecommunications

Department of aviation computer-integrated complexes

ADMIT TO DEFENSE

Head of the graduation department

______Viktor SINEGLAZOV

"____"____________2023

QUALIFICATION WORK

(EXPLANATORY NOTE)

GRADUATE DEGREE OF EDUCATION

"MASTER"

Specialty 151 "Automation and computer-integrated technologies"

Educational and professional program " Information support and engineering of aviation computer systems "

Topic: " Delayed route fuel consumption optimization system"

Performer: student of group IZ-225Ma Nikulin Artem Ivanovich

Supervisor: candidate of technical sciences, associate professor Smirnov Oleh Ihorovych

Consultant of the "Environmental Protection" section ______Radomska M.M.

Consultant of the "Labor Protection" section ______ Kazhan.K.I.

Normocontroller:______ Filyashkin M.K

Kyiv – 2023

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет аеронавігації, електроніки та телекомунікацій

Кафедра авіаційних комп’ютерно-інтегрованих комплексів

Освітній ступінь: магістр

Спеціальність 151 «Автоматизація та комп'ютерно-інтегровані технології»

Освітньо-професійна програма «Інформаційне забезпечення та інженерія авіаційних комп’ютерних систем»

ЗАТВЕРДЖУЮ

Завідувач кафедри

______Віктор СИНЄГЛАЗОВ

“_____”_____________2023 р.

ЗАВДАННЯ

на виконання кваліфікаційної роботи студента

Нікуліна Артема Івановича

1. Тема роботи: “ Система оцінки залишку пального при затримці посадки ”.

2. Термін виконання роботи: з 02.10.2023р. до 18.12.2023р.

3. Вихідні дані до роботи: Розробка системи оцінки залишку пального при затримці посадки в авіаційній сфері. Забезпечення надійності пов'язаних із виміром та управлінням залишком пального, з метою забезпечення оптимальних умов безпеки та ефективного управління авіаційним транспортом.

4. Зміст пояснювальної записки (перелік питань, що підлягають розробці): 1. Визначення основних функціональних та технічних характеристик системи; 2. Опис основних завдань системи, спрямованих на забезпечення ефективного виміру та управління залишком пального в умовах затримки посадки; 3. Визначення технічних вимог до системи, зокрема стосовно точності вимірювань

5. Перелік обов’язкового графічного матеріалу: 1. Структурна схема баків літака. 2. Структура комплексного планування польотів та управління порушеннями. 3. Передбачуваний профіль польоту. 4. Структура алгоритму визначення залишку палива на поточний момент часу. 5. Висновки.

6. Календарний план-графік

№	Завдання	Термін виконання	Відмітка про виконання
1	Отримання завдання	02.10.2023	
2	Формування мети та завдання	04.10.2023	
3	Аналіз актуальності проблеми	05.10.2023-11.10.2023	
4	Аналіз існуючих методів	13.10.2023-25.10.2023	
5	Опис об'єкта дослідження та його характеристика	25.10.2023-05.11.2023	
6	Підбір обладнання	08.11.2023-18.11.2023	
7	Ознайомлення з гідростатичним датчиком тиску	20.11.2023-27.11.2023	
8	Розрахунки залишку пального в баках літака за рахунок використання гідростатичного датчику тиску	03.12.2023-12.12.2023	
9	Написання висновків розрахунків та формування алгоритму	13.12.2023-17.12.2023	
10	Оформлення пояснювальної записки	17.12.2023	
11	Підготовка презентації	17.12.2023	

7. Консультанти з окремих розділів

Розділ	Консультант (посада, П. І. Б.)	Дата, підпис	
		Завдання видав	Завдання прийняв
Охорона праці	Катерина КАЖАН		
Охорона навколишнього середовища	Маргарита РАДОМСЬКА		

8. Дата видачі завдання 02.10.2023

Керівник: ______________Олег СМІРНОВ

Завдання прийняв до виконання _______________Артем НІКУЛІН

NATIONAL AVIATION UNIVERSITY

Faculty of Aeronautics, Electronics and Telecommunications

Department of aviation computer-integrated complexes

Educational degree: Bachelor

Specialty 151 "Automation and computer-integrated technologies"

Educational and professional program " Information support and engineering of aviation computer systems "

APPROVED

Head of Department

_______Viktor SINEGLAZOV

"____"___________2023

TASK

For the student's qualification work

Nikulin Artem Ivanovich

1. The thesis title: "The system for estimating the remaining fuel at boarding delays"

2. The term of the project: from 02.10.2023p. until 18.12.2023p.

3. Output data to the project: Development of a system for estimating the remaining fuel in the event of a landing delay in the aviation sector. Ensuring reliability related to the measurement and management of the remaining fuel, in order to ensure optimal safety conditions and effective management of aviation transport.

4. Contents of the explanatory note: 1. Definition of the main functional and technical characteristics of the system; 2. Description of the main tasks of the system, aimed at ensuring effective measurement and management of the remaining fuel in the conditions of the landing delay; 3. Determination of technical requirements for the system, regarding the accuracy of measurements

5. List of required illustrative material: 1. Structural diagram of aircraft tanks. 2. Structure of integrated flight planning and management of violations. 3. Estimated flight profile. 4. The structure of the algorithm for determining the remaining fuel at the current moment in time. 5. Conclusions.

№	Завдання	Термін виконання	Відмітка про виконання
1	Receiving the task	02.10.2023	
2	Formation of the goal and task	04.10.2023	
3	Analysis of the relevance of the problem	05.10.2023-11.10.2023	
4	Analysis of existing methods	13.10.2023-25.10.2023	
5	Description of the research object and its characteristics	25.10.2023-05.11.2023	
6	Selection of equipment	08.11.2023-18.11.2023	
7	Familiarization with the hydrostatic pressure sensor	20.11.2023-27.11.2023	
8	Calculations of the remaining fuel in the aircraft tanks due to the use of a hydrostatic pressure sensor	03.12.2023-12.12.2023	
9	Writing the conclusions of the calculations and forming the algorithm	13.12.2023-17.12.2023	
10	Issuance of an explanatory note	17.12.2023	
11	Presentation preparation	17.12.2023	

6. Planned schedule.

7. Consultants from individual departments

Section	Consultant	Date, signature	
		Issued the task	I accepted the task
Labor protection	Katerina KAZHAN		
Environmental protection	Marharyta RADOMSKA		

8. Issue date of the task 02.10.2023

Supervisor: __________Oleg SMIRNOV

The task was accepted by: __________Artem NIKULIN

РЕФЕРАТ

Пояснювальна записка кваліфікаційної роботи : «Система оцінки залишку пального при затримці посадки»

СИСТЕМА ОЦІНКИ ЗАЛИШКУ ПАЛЬНОГО, ГІДРОСТАТИЧНИЙ ДАТЧИК ТИСКУ, ПАЛИВНЕ ДЗЕРКАЛОР, ЗАТРИМКА ПОСАДКИ, ТОЧНІСТЬ ВИМІРЮВАНЬ.

Предмет дослідження: Розробка системи оцінки залишку пального при затримці посадки літака.

Мета кваліфікаційної роботи: Розробка та імплементація системи, яка використовує гідростатичний датчик тиску в баку літака для більш точного визначення залишку пального.

Метод дослідження: Аналіз літературних джерел, практичне впровадження технічних рішень, експериментальні вимірювання.

Об'єкт дослідження: Система оцінки залишку пального в баку літака.

Основні результати дослідження: Використання гідростатичного датчика тиску в системі оцінки залишку пального при затримці посадки дозволило досягти значного підвищення точності та надійності вимірювань. Розроблена система дозволяє ефективно враховувати вплив різних факторів, таких як тиск, температура і висота польоту, на визначення залишку пального.

Розроблена стратегія технічного захисту: Враховуючи значущість даних про залишок пального для безпеки польотів, в роботі визначено та реалізовано стратегію технічного захисту, яка включає в себе заходи шифрування та контролю доступу до системи.

Рекомендації та подальші напрями досліджень: Результати роботи можуть бути використані в практичній діяльності авіаційних підприємств для оптимізації систем оцінки залишку пального та підвищення безпеки польотів. Подальші дослідження можуть бути спрямовані на вдосконалення технічних рішень та розширення можливостей системи в різних умовах експлуатації літаків.

ABSTRACT

Explanatory note of the qualification work: "System of estimating the remaining fuel in the case of delayed landing"

FUEL REMAINING EVALUATION SYSTEM, HYDROSTATIC PRESSURE SENSOR, FUEL MIRROR, LANDING DELAY, MEASUREMENT ACCURACY.

The subject of the study: Development of a system for estimating the remaining fuel in the event of a delayed landing of the aircraft.

The purpose of the qualification work: Development and implementation of a system that uses a hydrostatic pressure sensor in an aircraft tank to determine the remaining fuel more accurately.

Research method: Analysis of literary sources, practical implementation of technical solutions, experimental measurements.

The object of the study: The system for estimating the remaining fuel in the aircraft tank.

The main results of the study: The use of a hydrostatic pressure sensor in the system for assessing the fuel balance during a landing delay made it possible to achieve a significant increase in the accuracy and reliability of measurements. The developed system allows you to effectively consider the influence of various factors, such as pressure, temperature and flight altitude, on determining the remaining fuel.

Developed technical protection strategy: Considering the importance of fuel remaining data for flight safety, the work defined and implemented a technical protection strategy, which includes encryption and system access control measures.

Recommendations and further directions of research: The results of the work can be used in the practical activities of aviation enterprises to optimize systems for estimating the remaining fuel and improve flight safety. Further research can be aimed at improving technical solutions and expanding the capabilities of the system in various conditions of aircraft operation

CONTENT

LIST OF ABBREVIATIONS

T - tetrahedron

FMS - fuel measuring systems

FM - fuel mirror

HPS - hydrostatic pressure sensors

NM - navigation network

ATMF - air traffic flow management

PPE - personal protective equipmen

INTRODUCTION

With the rapid development of the aviation industry and the increase in the volume of passenger and cargo transportation, the issue of effective management of aircraft resources, in particular fuel, is becoming increasingly important in the modern world. The increase in the cost of aviation fuel in recent years puts an extreme emphasis on the development and improvement of the system for estimating the remaining fuel, which allows to optimize its consumption and effectively manage resources.

This thesis is devoted to the development and implementation of a system for estimating the remaining fuel during a landing delay, which is based on the use of a hydrostatic pressure sensor. The selected technical solution is aimed at increasing the accuracy and reliability of determining the amount of fuel in the tanks during various stages of the flight, especially in conditions of delayed landing.

Over the past decade, the global aviation industry has been plagued with high and unpredictable aircraft fuel costs, becoming a burdensome factor for airlines and civil aviation enterprises. In the conditions of such a context, the improvement of the system of measurement and control of fuel residues with effective management of this strategic resource is ensured.

The main service of this work is the development and implementation of a system that uses a hydrostatic pressure sensor to provide accurate and reliable data about the remaining fuel during a landing delay. Considering the current economic challenges in the aviation industry, this system is aimed at optimizing the costs of the aircraft fleet and ensuring a high level of flight safety.

The thesis will consist of sections covering various aspects of the development and implementation of the residual fuel estimation system during landing delay. Analysis of literary sources, comparative analysis of existing systems, description of mathematical models and hardware, consideration of practical challenges and advantages of the system - these are only some aspects that will be reflected in the work. The results of the research will be created outside the boundaries of modern aviation technology and economics.

CHAPTER 1

STATEMENT OF THE PROBLEM OF DEVELOPING THE FUEL REMAINDER ASSESSMENT SYSTEM IN CASE OF LANDING DELAY

1.1 Relevance of the problem

The theme of this diploma continues the theme of the bachelor thesis: 'Optimizing fuel consumption during delayed flights'. It is then complemented by an additional system for the calculation of the remaining fuel during delayed flights.

Fuel is the main expenditure item that makes up the cost of an air ticket. According to industry experts, fuel costs account for 26-40% of the ticket price. The recent fuel price increase was the highest in the last seven and a half years due to the threat of war in Ukraine and disruptions in oil supply.

The price of a barrel of Brent North Sea oil rose by 6% to USD 111.38 per barrel during this period. This is the highest price since early July 2014. Red approaches (called 'go-arounds' by pilots) are practiced for various reasons, such as bad weather, runway closures and tailwind approaches.

1.2 Airfare prices will increase

[3] According to American Express Global Business Travel, worldwide airfares will increase by 12% on Europe-Asia routes and 10% on North America-Asia routes next year.

Amex GBT's Air Monitor 2023 report says Asia, where growth has slowed due to covid travel restrictions, will see the biggest changes as growth accelerates. Inflation, rising fuel prices and capacity constraints are among the factors driving fare increases around the world. Rising fares between Europe and Asia also reflect the impact of rerouting around Russian airspace, which has been closed by a series of laws since the invasion of Ukraine.

Ticket prices are already higher than before the pandemic, which has hurt travel and forced airlines to reduce capacity. Key markets such as the US and Europe have struggled to cope with increased demand following the lifting of restrictions.

The 12% price increase on Asia-Europe routes applies to economy class fares, while business class tickets on intercontinental flights are expected to increase by an average of 7.6%. Fares in business class between North America and Asia could increase by 5.6%.

According to the report, one of the most significant changes will affect business class tickets in Australia, where a growth of nearly 19% is projected. Although demand has returned to pre-Covid crash levels, airlines are reducing capacity to cope with issues such as staff shortages and rising fuel costs, pushing ticket prices higher.

Fig. 1.1 Reasons for reduced airport capacity

Weather conditions: adverse weather conditions such as fog, high winds, storms, and snowfall can increase coverage, reduce flight safety and cause flight delays and cancellations.

Traffic conditions: during periods of heavy traffic, airports may have a higher number of arrivals and departures, which can cause delays and congestion.

Seating restrictions: some airports may have a limited number of runways, gates and baggage claim areas. These restrictions can limit access to the airport and limit the number of flights.

Technical problems: aircraft maintenance issues and equipment failures in the traffic control system can cause delays and capacity issues.

Construction and renovation: construction of new facilities or renovation of existing airports can temporarily reduce the use of additional components.

Social and political events: events such as work stoppages by airport employees or political security measures can cause problems and reduce capacity.

Staff maintenance and training: lack of qualified personnel and inadequate aircraft and equipment maintenance can lead to breakdowns and reduced efficiency. All these factors can affect airport operations and lead to temporary capacity constraints.

1.3 Flight planning

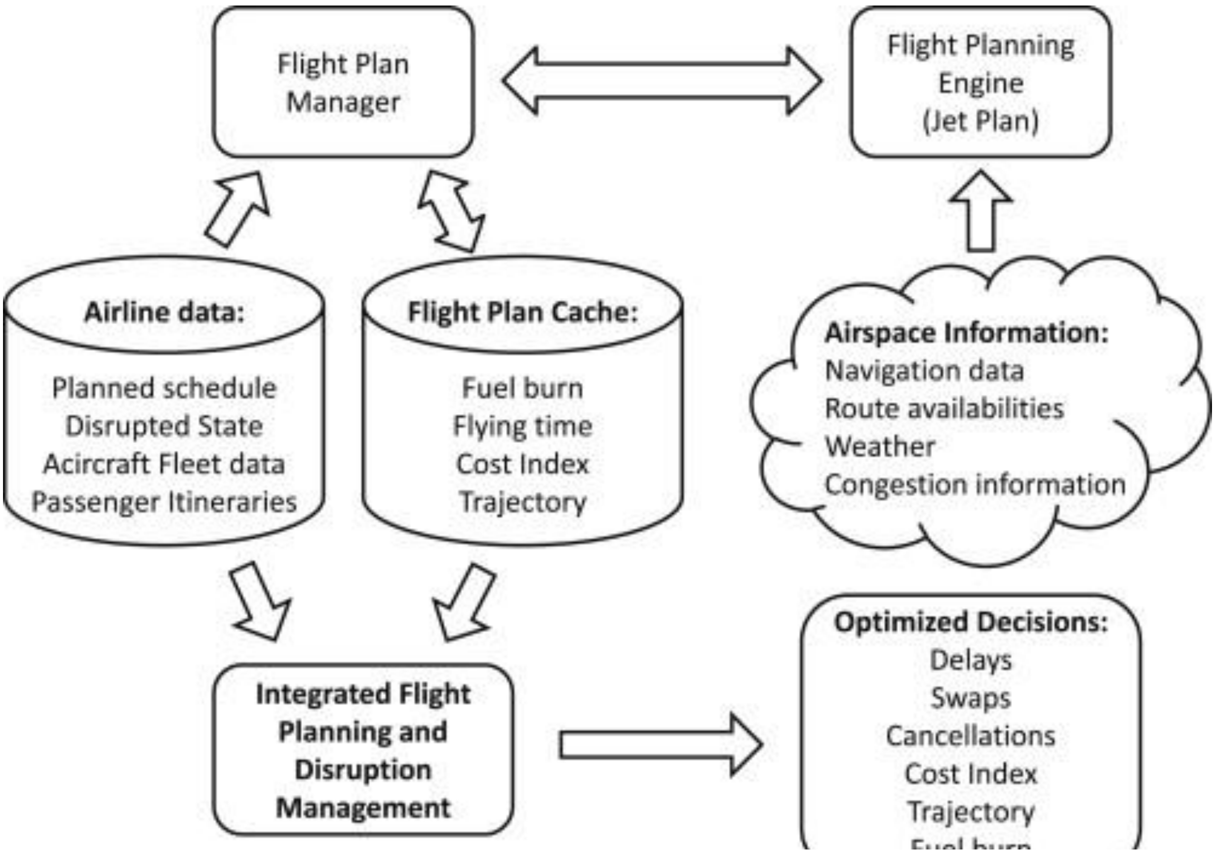

Fig. 1.2 The structure of complex flight planning and management of violations.

Ukraine fully participates in Euro control operations as the managing controller of the Air Navigation Network (NM) and implements Air Traffic Flow Management (ATFM) functions through the NMOC.

Air traffic flow management is a service established to ensure the safe, orderly, and expeditious movement of air traffic by maximizing the use of traffic control capabilities and ensuring that air traffic capacity is maintained to meet police requirements.

The purpose of ATFM is to ensure the smooth flow of air traffic when extremely high temperatures are expected over ATC traffic flow technology. This includes organizing and directing movement in a safe, orderly, rapid, and formal manner - it is possible. The system's ATC reflector capability provides a service that aggregates many aircraft flying over a given airspace area at a given time.

OPIA helps ATC achieve its core purpose and make the most efficient use of airspace and airspace capacity. Effective utilization requires cooperation and collaboration with ATC support and airspace users. Appropriate airspace flows may not always be possible due to various constraints, such as conflicting user requirements, inaccurate forecasting of weather conditions and air navigation system constraints. In such cases, measures such as airspace flow management need to be considered, especially when the ATC system can no longer handle all airspace dimensions. Such measures often result in pre-departure flight delays, in-flight delays, diversions, and detours, disrupted flight schedules, seat and fuel penalties for operators of low-weight aircraft, and congestion at airfields and other locations and facilities.

Integrated flight planning and airspace disturbance management are important elements of air navigation and flight safety. These functions are performed to ensure the efficient and safe movement of aircraft during all phases of flight. A framework for integrated flight planning and disturbance management is presented below.

1.3.1 Key points of flight planning

Route determination: at this stage, the aircraft route is selected based on several factors, including weather, airspace, and altitude.

Determining departure and arrival times: determining the departure and landing times of the aircraft and monitoring airport schedules and runway availability.

Preparing route data: developing a navigation plan considering destinations, waypoints, and other flight parameters. vi.

Liaising with airlines: liaising with airlines and airline pilots to ensure that flight clearances are obtained, and special instructions are given.

1.3.2 Control of airspace violations

Tracking and surveillance: a tracking and surveillance system monitors the movements of all aircraft in each sector of airspace.

Situation detection: b. Situation detection: if there is a violation in a sector of the airspace (e.g. unauthorized entry into restricted areas), the system will detect it and raise an alarm.

Communication and intervention: the air sector concerned communicates with the violator (by radio, through the air traffic control center) and gives instructions for flight coordination or forced landing.

Traffic control: air traffic controllers and aviation authorities coordinate the movement of aircraft to prevent accidents and ensure safety.

1.3.3 Systems and technology

Automated systems: modern automated traffic and navigation control systems are used for effective flight control and monitoring of violations. Radio communications: pilots and air traffic controllers use radio communications to exchange messages and energy. Radar and detection systems Radar and detection systems assist in flight tracking and control.

1.3.4 Training and certification

Pilot training: pilots should be trained to comply with the rules and procedures, including control of airspace violations.

Personnel certification: Personnel qualifications: dispatchers and other personnel involved in flight control should hold appropriate certificates and qualifications.

Effective integrated flight planning and airspace violation management play an important role in ensuring the safety and efficiency of civil aviation.

Systems and processes are developed and implemented by national professional bodies and authorities.

1.3.5 Basic criteria for calculating fuel supply

Each flight must be provided with enough fuel, considering the margin for deviation from the planned route.

The design take-off weight of the loaded and fueled aircraft must not exceed the maximum allowable weight (MTOW).

the design landing weight of the aircraft at the landing aerodrome must not exceed the maximum permissible weight (MLW).

The estimated fuel supply should not exceed the volume of fuel tanks.

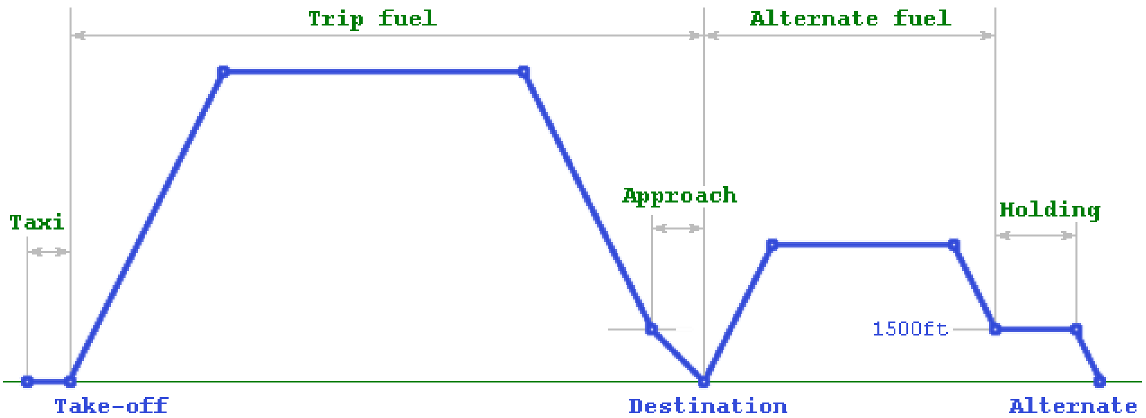

Fig. 1.3 The assumed flight profile

The standard fuel calculation has several stages:

- Taxi fuel - fuel consumption for engine operation during ground operations.

- APU fuel - fuel consumption for auxiliary power unit operation.

- In-flight fuel - fuel consumption per flight on the route, including take-off, altitude, staggered flight, descent, and landing approach to the destination airport.

- En route fuel supply or Contingency fuel – additional fuel reserve in case of unforeseen circumstances along the route, usually 5% of fuel for the flight.

- Reserve fuel - fuel consumption for the maintenance of a reserve airport. This includes maintaining a second entry (second circle) from a designated altitude, climb, flight to the echelon, descent and landing at the reserve square. If the flight plan includes more than one alternate airport, the standby fuel should cover the flight to the farthest alternate airport.

- Standby fuel - fuel consumption per 30-minute flight at 1,500 feet above runway altitude in the standby area of an alternate airport. If an alternate airport is not specified in the flight plan, the standby fuel should provide for 60 minutes of standby flight over the destination airport.

- Additional fuel - additional fuel at the captain's discretion.

Terminology and requirements may vary from document to document.

1.4 Cruise Speed

1.4.1 The importance of cruise speed control

Controlling cruising speed is important for the following reasons

Fuel consumption: determining the optimum speed can minimize fuel consumption during flight.

Increased range: proper speed control can increase range, enabling longer distances to be flown without additional stops.

Safety: Maintaining a constant speed makes the aircraft more stable and easier to control in different weather conditions.

1.4.2 Cruise speed control methods

Cruising speed can be regulated in the following ways.

The pilot determines the optimum speed depending on the altitude and weight of the aircraft using tables and charts provided by the aircraft manufacturer.

Autopilot: modern airplanes are equipped with an autopilot that maintains a given cruising speed and can monitor changes in speed.

Air traffic controllers: air traffic controllers can give speed instructions to pilots to ensure that the aircraft can fly safely in the airspace.

1.4.3 Effects of cruise control.

Cruise control can affect many aspects of flight, including

Economy: Choosing the right speed affects the economy of the flight, i.e. the ticket price and the profitability of the airline.

Distance flown speed control determines the distance an aircraft can fly without additional refueling.

Flight time: speed also affects the overall flight time or flight duration.

1.5 Sensor for measuring fuel quantity

Fuel gauges can be used to measure the total supply of all tanks and the amount of fuel in each tank separately. To avoid unacceptable shifts in the aircraft's center of mass, it is necessary to know how the fuel is distributed between the tanks to determine the correct sequence of fuel consumption from the tanks. Tank switching is controlled by automatic fuel metering devices.

[4] Since it is not possible to directly measure the volume (weight) of fuel in an aircraft, indirect measurement methods are used that relate the volume (weight) of fuel to a value that is functionally easier to determine.

Most methods of measuring fuel volume are based on measuring the liquid level (height of the liquid column). However, fuel gauge scales are displayed in volumetric units (liters) or kilograms. The calibration of the scale therefore depends on the size and shape of the fuel tank.

1.6 Classification of aviation fuel gauges

When fuel gauges are classified according to the operating principle of the sensing element, the following commonly used types can be noted:

- Float type: measuring the fuel level (volume) by means of a float floating on the surface; - Manometric type: measuring the pressure (weight) of the fuel column by means of a pressure gauge; - Manometric type:

- The manometric type measures the pressure (weight) of the fuel column using a pressure gauge.

- Capacitive, using a special capacitor to measure the fuel level (volume), whose capacity is functionally related to the fuel level in the tank.

Float fuel gauges can be divided into mechanical and electrical types depending on the method used to convert the position of the float into a transferable value.

Float and volumetric fuel gauges measure the volumetric quantity of fuel, while pressure gauges measure the weight quantity. Fuel volume is usually expressed in volumetric units (liters), so fuel gauge readings are only accurate for fuels with a specific specific gravity.

Fuel gauges must be positioned remotely. Electric fuel gauges fulfill this requirement. Mechanical fuel gauges are rarely used in the aviation industry because they cannot be operated remotely. The most used are capacitive and float fuel gauges, described in this section.

The fuel gauge error should not exceed 2-3% of the actual amount of fuel remaining in the tank.

Fuel gauge readings are accurate only if the airplane is in a steady, straight line of flight. Otherwise, instrument readings will be inaccurate.

The aircraft's fuel supply is very high and incorrect fuel consumption from individual tanks can cause the aircraft to be out of alignment. To correct this, aircraft are equipped with special automatic machines that produce fuel from a group of tanks according to a specific program. Such machines form an integrated system with the fuel gauge and are called fuel metering and consumption systems.

1.7 Methods for measuring fuel quantity

Most methods of measuring fuel quantity are based on measuring the fuel level.

The amount of fuel υ (in units of volume) and the level h are related to each other by a functional relationship determined by the shape of the fuel tank.

The amount of fuel in the tank can be measured by the following most common methods

- Gravimetric hydrostatic method.

- Floating

- Acoustic method

- Capacitive method
- Inductive method
- Resistance
- Radio waves
- Radioisotopes

Weighing methods weigh fuel tanks directly using strain gauges mounted on tank connections.

Hydrostatic methods are based on the level dependence of the hydrostatic pressure of the fuel.

The buoy method measures the linear displacement of a buoy floating on the fuel surface relative to a vertical guide or the angular displacement associated with a lever buoy.

The acoustic method is based on the properties of ultrasonic vibrations reflected from the interface between two media. The fuel level in the tank is measured by positioning from above or below.

The capacitance method is based on the fact that the capacitance of a capacitor in the fuel tank depends on the fuel level. The capacitance varies because its dielectric constant is different from the dielectric constant of air.

The induction method is based on the dependence of the inductance of the coils in the tank on the fuel level. The inductance changes due to changes in the electrical losses in the liquid. These losses are more pronounced in conductive liquids and this method is applicable.

The resistance method is based on the dependence of the active resistance of the resistors in the fuel tank on the fuel level. The resistance changes with deflection with fuel. This method is suitable for measuring the liquid level of conductive liquids.

The radio interferometry method (radio interferometry) is based on the dependence of the position of the nodes of the standing electromagnetic wave generated in the coaxial line on the liquid level when the incident and reflected waves from the measured liquid level are added together.

The radioisotope method is based on measuring the radiation intensity as the radioisotope passes through the liquid layer whose liquid level is being measured.

Take a closer look at aircraft fuel metering systems based on hydrostatic sensors.

1.8 Fuel measuring system of an aircraft based on hydrostatic pressure sensors

The creation of a system for measuring the fuel level in an airplane based on hydrostatic sensors is considered.

The system will make it possible to measure the fuel level in the tank during flight and will be more efficient and accurate compared to traditional methods, such as the use of float or capacitive fuel level sensors.

Modern aviation requirements for accuracy and reliability emphasize the importance of the proposed system, which not only reduces the complexity of the electromechanical design, but also reduces weight and size characteristics.

The proposed technology based on hydrostatic sensors and computer data processing opens new perspectives for improving the efficiency of refueling systems and can be successfully applied for both ground and air calibration.

1.8.1 Methodological error correction and design simplification

Errors in float and capacitive fuel gauges consist of the following factors:

- Errors due to longitudinal and lateral movements and acceleration of the aircraft.

- Errors due to incorrect installation of the fuel tank or errors related to the size obtained during calculation and calibration; and

- Temperature errors due to changes in fuel temperature or fuel type in the tank.

- Errors due to changes in supply voltage.

The first three errors are procedural. Errors related to incorrect fuel tank installation or temperature errors can be compensated for by adding additional calibration schemes, but it is not always successful to compensate for errors due to changes in the angular orientation of the aircraft or the tilt of the 'fuel mirror' caused by the acceleration effect on the aircraft It is not necessary to design an algorithmic compensator.

Analysis of existing aircraft fuel measuring systems (FMS) using float or capacitive fuel level sensors has shown that these systems measure the fuel level in aircraft tanks with sufficient accuracy only during level flight. During the evolution of the aircraft, the measurement of fuel levels in such FMSs introduces significant methodological errors. In addition, FMS have a highly complex electromechanical design and large weight and size characteristics that collectively affect the overall reliability of such vehicles. Therefore, research into the development of fuel measurement systems that minimize such methodological errors is of great importance.

1.8.2 Effective measurement of fuel remaining on board

Known methods using float or capacitive fuel remaining sensors to measure fuel remaining in the tanks of modern aircraft cannot measure fuel remaining in the tanks during maneuvers where pitch and roll angles change significantly. [1] Under flight maneuvering conditions, the methodological error increases significantly and can lead to undesirable results during long duration maneuvers. For the above reasons, in order to obtain stable measurements of the remaining fuel level, new approaches should be used to create systems for measuring the remaining fuel level in aircraft tanks with high reliability and minimal weight and dimensions.

1.8.3 Functioning of FMS based on Hydrostatic Pressure Sensors

Let's consider the principle of operation of FMS based on hydrostatic pressure sensors (HPS) on the example of determining the volume of fuel in an airplane tank made in the form of a parallelepiped with edges a, b, c with fuel "mirror height" h_{fm}. [2] The base of the parallel line is tied to the horizontal geotopic triangle OENH, which in this case is considered instrumental. The course angles Ψ, pitch ϑ and roll Υ of the aircraft are zero in this case.

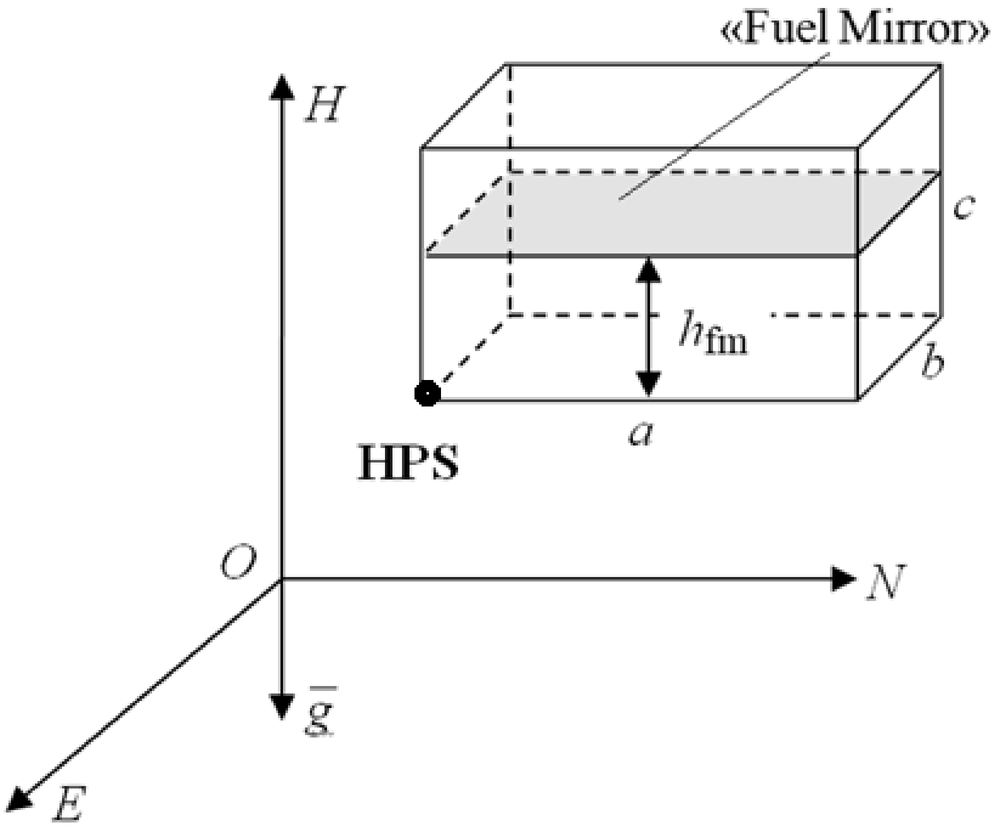

Fig. 1.4 Determination of the volume of fuel in a tank in the form of a parallelepiped

According to the readings of the HPS, which is in one of the vertices of the base of the parallelepiped, we can calculate the height of the "fuel mirror" (FM) plane h_{fm}. According to Pascal's law

$$P_{h_{fm}} = \rho \cdot g \cdot h_{fm}; \qquad h_{fm} = P_{h_{fm}} / (\rho \cdot g), \quad (1)$$

where $P_{h_{fm}}$ is hydrostatic pressure of a liquid with constant density in a homogeneous field of gravity: -ρ - density of the liquid; g - acceleration of free fall.

The volume of fuel in the tank $V_{h_{fm}}$ at height h_{fm} is calculated from the formula of parallelepiped volume:

$$V_{h_{fm}} = abc = abh_{fm} \quad (2)$$

In modern airplanes, fuel tanks are usually located on the wings and fuselage of the aircraft and have a shape like a parallelepiped. To solve the problem of finding the fuel volume of each tank, it is proposed to divide the area into nested volume figures, calculate the fuel volume in each of them separately, and find the total fuel volume as the sum of the fuel volumes of the figures nested in the tank. In this paper, the tetrahedron (T) is considered as the inscribed volume figure.

1.9 Conclusion

In the world of the aviation industry, fuel is defined as a key cost element, forming a significant part of the cost of air tickets. The current rise in fuel prices, caused by geopolitical and economic difficulties, significantly increases the operating costs of airlines and the cost of flights.

In the context of the technical aspects of fuel level measurement in aircraft, problems with the accuracy and reliability of existing float and capacitive sensors have been identified. These measurement difficulties occur especially when the aircraft is maneuvering, which can lead to inaccurate fuel remaining readings and, accordingly, unpredictable consequences.

For further research and development of more accurate and effective methods of measuring the fuel level in aircraft tanks, we will consider in the third part the possibility of using a hydrostatic pressure sensor.

CHAPTER 2

STATISTICS OF INCREASED PASSENGER FLOW AND DELAYS

2.1 Punctuality of Ukrainian airlines

Ukraine's largest airline, UIA, operated 91% of 2,026 flights from the country's airports without delay in January 2020 and took second place in the ranking, according to statistics released by the Ministry of Infrastructure. At the same time, the average punctuality of Ukrainian airlines was 85.9% with the number of flights 3378.

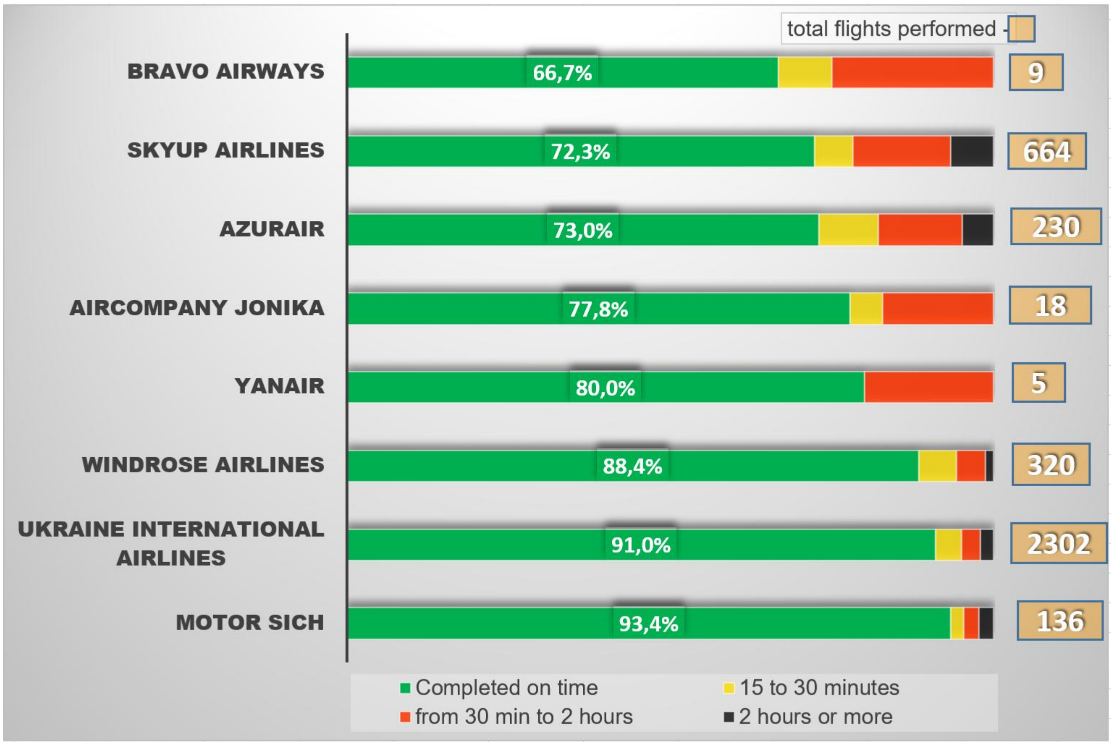

Fig. 2.1 Punctuality of Ukrainian airlines in January 2020

Motor Sich — 93.4% of flights were completed on time.

UIA - 91%.

"Wind Rose - 88.4%.

YanAir - 80%.

Jonika Airlines - 77.8%.

Azur Air Ukraine - 73%.

SkyUp - 72.3%.

Bravo Airlines - 66.7%.

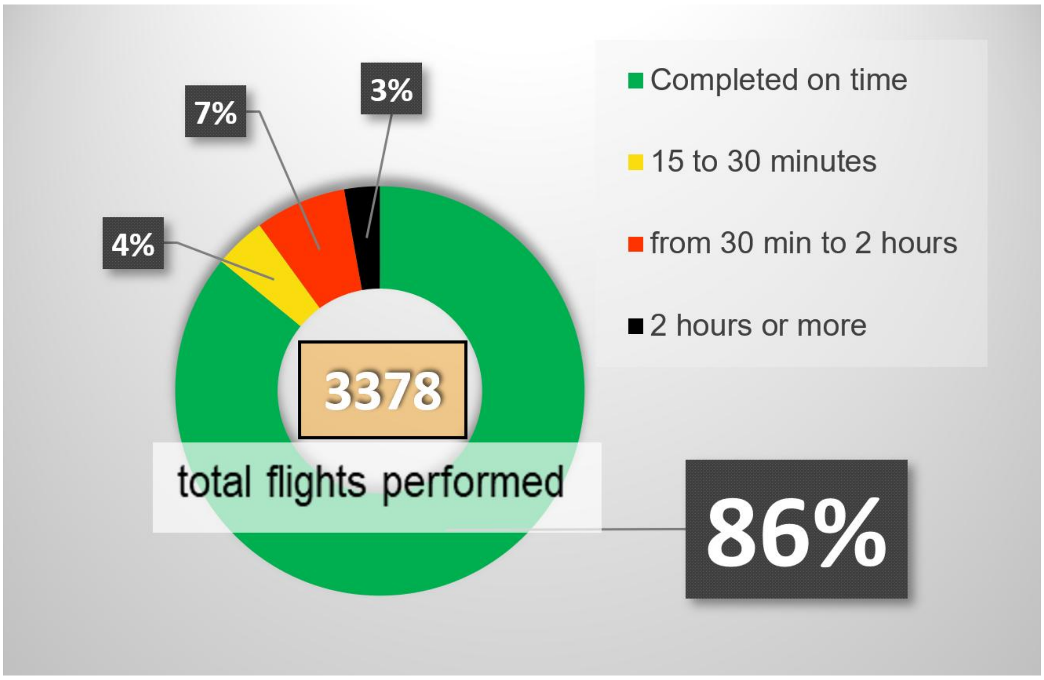

Fig. 2.2 Total flight performed

2.2 Flight delay in Europe

[5] Flight delays in EU member states increased by more than 400% year-on-year. This was reported by RBC-Ukraine citing a statement by Airlines for Europe (A4E), the EU's largest airline association responsible for 70% of European air traffic.

In an official statement, A4E said that flight delays in the EU have increased by more than 400% on average as Europe's airspace capacity is unable to cope with growing demand. The association warned that the gap between airline demand and European airspace capacity could remain high due to the EU's inability to provide sufficient airspace capacity.

The warning came from the annual report of the European Single Air Performance Review Body (PRB). The report points out that the main causes of delays are due to insufficient air traffic control (ATS) capacity as well as the effects of other factors such as weather and the war in Ukraine. The average departure delay from all causes was 19.03 minutes per flight.

Furthermore, besides airport capacity issues, Air Navigation Service Providers (ANSPs) are not ready to resume air traffic and in some places the network has been disrupted due to the war in Ukraine.

'Heavy traffic and high passenger demand will continue to impact airline operations and inconvenience millions of passengers. This can be avoided if Europe improves the system in every way and reduces the gap between demand and capacity in European airspace. - The A4E statement said.

Fuel tank float sensors and capacitive pressure sensors can be installed on different aircraft types.

Examples of the use of such sensors include the world's most popular series of commercial airliners, such as the Boeing 737, Airbus A320 and aircraft from other manufacturers.

The Boeing 737 is one of the most popular aircraft series in the world. More than 10,000 737 series aircraft have been built throughout its production history. It probably accounts for about 30-35% of the total passenger aircraft fleet in the world.

The Airbus A320 is another highly successful aircraft family. According to the latest data, more than 9,000 A320 series aircraft have been produced. It could account for about 30-35% of the world's total passenger aircraft fleet.

2.3 Air activation

According to the State Aviation Administration, the number of passengers passing through Ukraine's airports in 2018 increased by 24.5% to 20.55 million, of which 18.36 million were passengers arriving on international flights. This is an absolute record in Ukrainian history. Almost 98% of all passenger traffic and 99% of cargo traffic is concentrated at the country's seven airports: Boryspil, Kyiv (Zryany), Odessa, Lviv, Kharkiv, Dnipro and Zaporizhia. The main hub airports 'Boryspil' and 'Kyiv' ('Zryani') account for 75% of total passenger traffic.

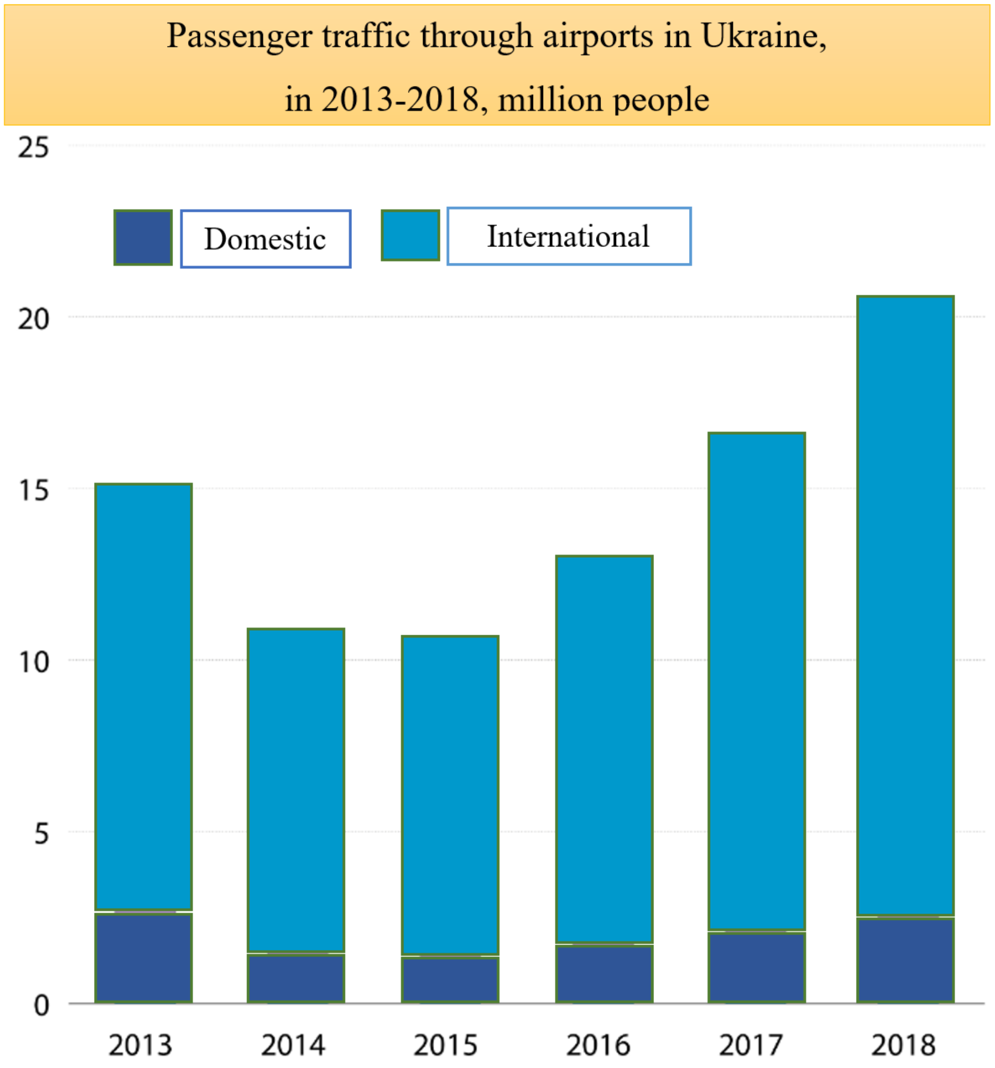

Fig. 2.3 Passenger traffic through Ukrainian airports from 2013 to 2018

2.4 Fuel price

Fig. 2.4 Fuel price statistics from 2018 to 2023

To demonstrate the increase in ticket prices due to the increase in fuel costs, we will compare the cost of flights from Riga to Odessa from April 2020 to April 2022.

For calculations we will take the price from AirBaltic - 78.99 euros or 2447 hryvnias (for convenience rounded up to 2500)

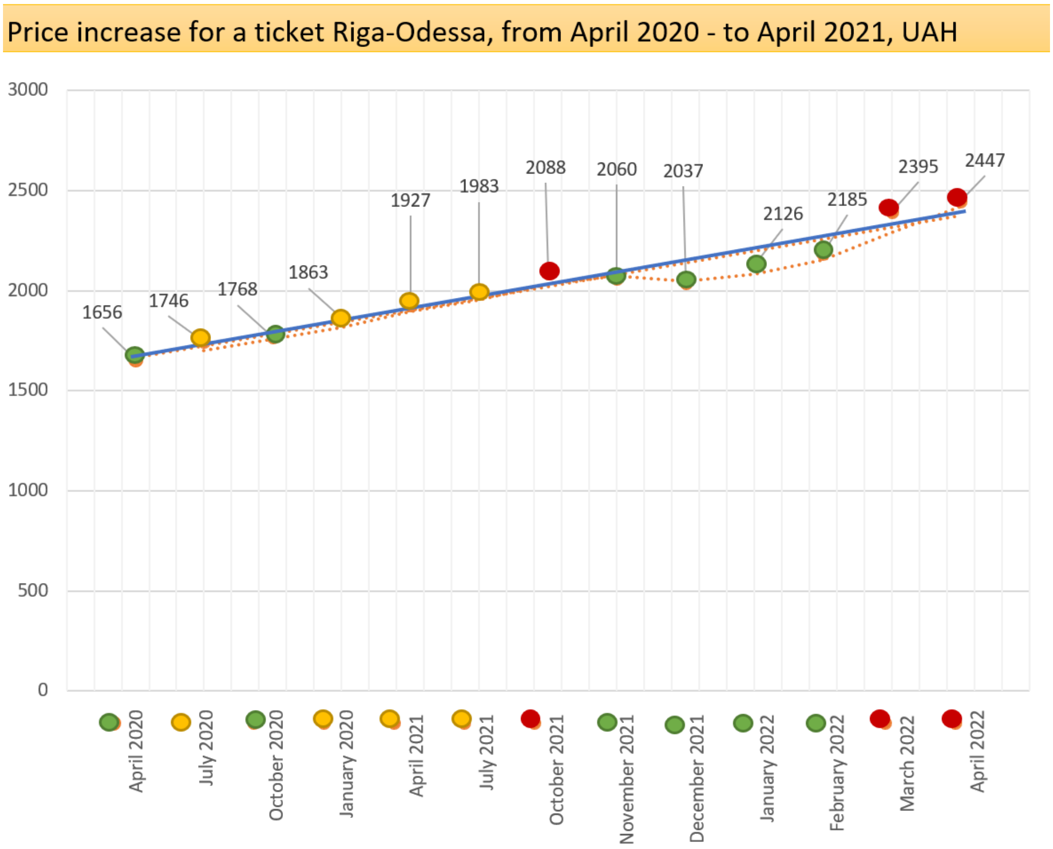

Fig. 2.5 The cost of an air ticket from Riga to Odessa from 2020 to 2023

2.5 Conclusion

From statistical data, we can determine the steady growth of passenger traffic in Ukraine from 2015 to 2018, in particular, on international flights, as well as record the growth of production and import of aviation fuel due to increased demand. It was noted that Boryspil and Zhulyany serve about 75% of passenger traffic. That in certain periods of the year or under certain conditions can lead to flight delays.

If we talk about the post-war period, it should be noted that after the end of the war, air travel in Ukraine will resume, once again becoming available to citizens. However, the increase in the cost of fuel will lead to an increase in the price of air tickets. This will certainly affect the availability of air travel for passengers in the past.

Taking this into account, it is necessary to consider the possibilities of optimizing the use of fuel. Application of new technologies and strategies in the aviation sector that will contribute to maintaining the efficiency and competitiveness of airlines in conditions of rising fuel costs.

CHAPTER 3

CALCULATIONS

3.1 The volume of fuel in the aircraft tank

In the modern aviation industrial environment, much attention is paid to the issue of efficient use of fuel in aircraft. Maintaining the optimal level of fuel in the aircraft tank is of great importance both for reducing operating costs and for the environmental sustainability of the aviation industry.

In this section, we will consider the possibilities of accurate calculation of the amount of fuel in the aircraft tank. The focus will be on the use of a hydrostatic pressure sensor to measure the fuel level. Hydrostatic pressure sensors have proven to be quite accurate and reliable means of measurement, and their use can greatly facilitate the task of determining the amount of fuel on board an aircraft.

For example, let us consider the possibility of partitioning a parallelepiped into tetrahedrons. The parallelepiped, as can be seen from Fig. 2, is partitioned into four tetrahedrons:

- Tetrahedron 1, with vertices: 1, 3, 4, 8.
- Tetrahedron 2, with vertices: 1, 2, 3, 6.
- Tetrahedron 3, with vertices: 3, 6, 7, 8.
- Tetrahedron 4, with vertices: 1, 5, 6, 8.

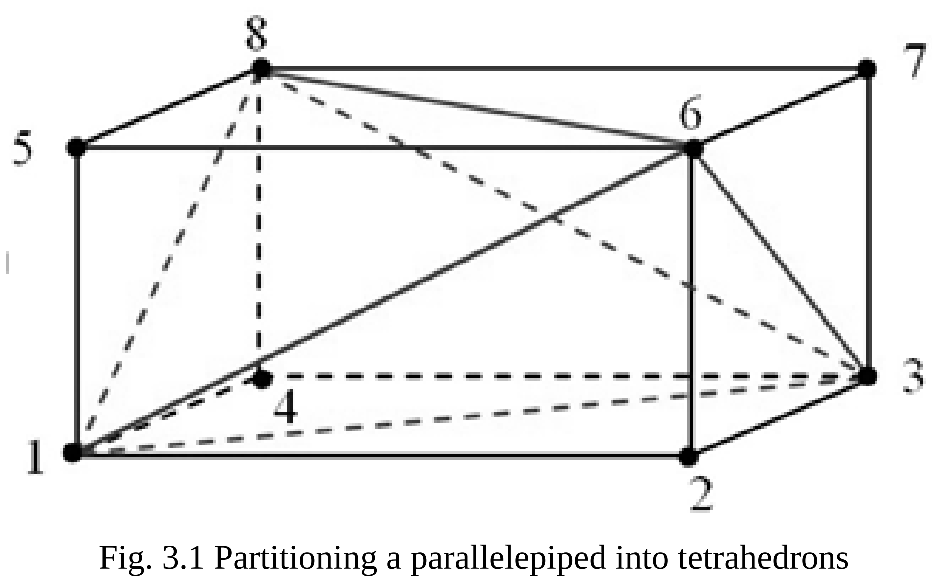

Fig. 3.1 Partitioning a parallelepiped into tetrahedrons

Fuel residue volume Vx for tetrahedron No.2 with vertices 1,2, 3,6 (Fig.3) in the coordinate system of the instrument trihedron *OENH* and HPS located in one of the base vertices can be determined from the following relations:

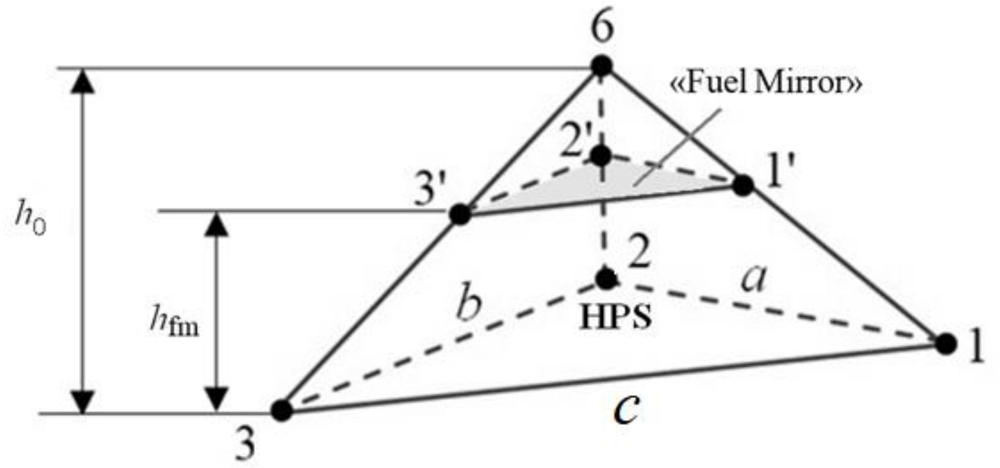

Fig. 3.2 Volume of fuel residue for the tetrahedron

Total volume of the tank Vo (volume of the tetrahedron tetrahedron with vertices 1,2,3,6 and two mutually perpendicular side planes of the tetrahedron):

$$V_0 = \frac{1}{3} S h_0; \quad S = \frac{1}{2} ab; \quad V_0 = \frac{1}{6} abh_0,$$

where *a,b* is lengths of faces T, h_0 - calculated height of T according to the information from HPS at vertex

The volume of the unfilled part of the tank V_{up} with vertices in points 1', 2', 3', 6 is determined by the lengths of the segments of the edges of the unfilled part of the tetrahedron *a*' and *b*' cut off by the FM. The sought segments *a*' and *b*' are found from the relations for rectangular similar triangles. Through similar triangles formed by vertices 1, 2, 6 and 1', 2', 6' the segment *a*' is found, and through triangles with vertices 3, 2, 6 and 3', 2', 6' the segment *b*' is determined:

$$a' = h_{\mathrm{fm}} \frac{b}{h_0}; \quad b' = h_{\mathrm{fm}} \frac{a}{h_0};$$

$$V_{\mathrm{up}} = \frac{1}{6} a'b' \left(h_0 - h_{\mathrm{fm}} \right).$$

The desired fuel volume is defined as the difference between V_0 and the volume of the unfilled part of the tetrahedron V_{up}:

$$V_x = V_0 - V_{\mathrm{up}}.$$

To find the fuel residue in a tetrahedron of arbitrary shape, to calculate the lengths of the segments obtained from the intersection of the fm with the edges of the tetrahedron, it is necessary to recalculate the parameters of the vector perpendicular to the FM plane $h_{\mathrm{fm}}\{0, h_{\mathrm{fm}}, 0\}$ on its inclined edges. Such a problem of computing the volume V_x in segments is solvable, but requires the use of a rather complex algorithm.

One of the variants of another solution of the problem of fuel residue determination for an arbitrary tetrahedron can be realized with the transition from volume calculation in segments to volume calculation by coordinates of fm intersection with tetrahedron edges.

In general, the equation of the plane, linear with respect to Cartesian rectangular coordinates is:

$$Ax + By + Cz + D = 0,$$

where A, B and C not equal to zero simultaneously define the plane.

The equations of three side planes of a tetrahedron of arbitrary shape with one HPSS in one of the vertices of the base, which coincides with the horizontal plane of the instrumental tetrahedron OENH, can be represented in the following form:

- plane with vertices 1,6,3

$$A_1 x_{ENH} + B_1 y_{ENH} + C_1 z_{ENH} + D_{1ENH} = 0; \quad (3)$$

- plane with vertices 1,6,2

$$A_2 x_{ENH} + B_2 y_{ENH} + C_2 z_{ENH} + D_{2ENH} = 0; \quad (4)$$

- plane with vertices 2,6,3

$$A_3 x_{ENH} + B_3 y_{ENH} + C_3 z_{ENH} + D_{3ENH} = 0, \quad (5)$$

Where

$$D_{1ENH} = Ax_{10ENH} + By_{10ENH} + Cz_{10ENH};$$
$$D_{2ENH} = Ax_{20ENH} + By_{20ENH} + Cz_{20ENH};$$
$$D_{3ENH} = Ax_{30ENH} + By_{30ENH} + Cz_{30ENH}.$$

The parameters of the planes with respect to the *OENH* coordinate system are assumed to be known.

The equation of the FM plane passing through one of its points and perpendicular to the vector **N** {*A*, *B*, C} can be represented in the following form

$$A(x - x_0) + B(y - y_0) + C(z - z_0) = 0; \quad (6)$$

In the case of parallelism of the FM plane to the *OENH* plane (*A*=0, *C*=0), equation (6) will take the following form:

$$B(y - y_0) = 0,$$

whence at N {0, h_{fm}, 0}

$$D = By_0;$$
$$y = y_0 = h_{\mathrm{fm}ENH}, \quad (7)$$

for all points of the FM.

The x and y coordinates of the FM for points 1', 2', 3' (Fig. 3) are found as the intersection of the tetrahedron planes (3) … (5) with the FM plane (7).

For the coordinates of points 1', 2', 3', respectively, we have three systems of equations and their solution with respect to the three points of intersection of the FM with the tetrahedron:

- for coordinates of point 1'(x'_{1ENH} , h_{fm}1', z'_{1ENH}):

$$
\begin{aligned}
&A_1 x_{1ENH} + h_{\text{fm}} + C_1 z_{1ENH} + D_{1ENH} = 0;\\
&D_{1ENH} = Ax_{01ENH} + By_{01ENH} + Cz_{01ENH};\\
&A_2 x_{1ENH} + h_{\text{fm}} + C_2 z_{1ENH} + D_{2ENH} = 0;\\
&D_{2ENH} = Ax_{02ENH} + By_{02ENH} + Cz_{02ENH};\\
&z'_{1ENH} = -\frac{A_2 D_{1ENH} - D_{2ENH} h_{\text{fm}}}{C_{1ENH}};\\
&x'_{1ENH} = \frac{h_{\text{fm}}(C_{2ENH} - C_{1ENH}) + C_2 D_{1ENH} - C_1 D_{2ENH}}{A_2 C_{1ENH} - A_{21} C2_{ENH}}.
\end{aligned}
\tag{8}
$$

- for coordinates of point 2'(x'_{2ENH} , h_{fm}2', z'_{2ENH}):

$$
\begin{aligned}
&A_2 x_{2ENH} + h_{\text{fm}} + C_2 z_{2ENH} + D_{2ENH} = 0;\\
&D_{2ENH} = Ax_{02ENH} + By_{02ENH} + Cz_{02ENH};\\
&A_3 x_{3ENH} + h_{\text{fm}} + C_3 z_{3ENH} + D_{3ENH} = 0;\\
&D_{3ENH} = Ax_{03ENH} + By_{03ENH} + Cz_{03ENH};\\
&z'_{2ENH} = -\frac{A_3 D_{2ENH} - D_{3ENH} h_{\text{fm}}}{C_{2ENH}};\\
&x'_{2ENH} = \frac{h_{\text{fm}}(C_{3ENH} - C_{2ENH}) + C_3 D_{2ENH} - C_2 D_{3ENH}}{A_3 C_{2ENH} - A_2 C_{3ENH}}.
\end{aligned}
\tag{9}
$$

- for coordinates of point 3'(x'_{3ENH} , h_{fm}3', z'_{3ENH}):

$$
\begin{aligned}
&A_1 x_{1ENH} + h_{\text{fm}} + C_1 z_{1ENH} + D_{1ENH} = 0;\\
&D_{1ENH} = Ax_{01ENH} + By_{01ENH} + Cz_{01ENH};\\
&A_3 x_{2ENH} + h_{\text{fm}} + C_3 z_{2ENH} + D_{3ENH} = 0;\\
&D_{3ENH} = Ax_{03ENH} + By_{03ENH} + Cz_{03ENH}; \qquad (10)\\
&z'_{3ENH} = -\frac{A_3 D_{1ENH} - D_{3ENH} h_{\text{fm}}}{C_{1ENH}};\\
&x'_{3ENH} = \frac{h_{\text{fm}}(C_{3ENH} - C_{1ENH}) + C_3 D_{1ENH} - C_1 D_{3ENH}}{A_3 C_{1ENH} - A_1 C_{3ENH}}.
\end{aligned}
$$

According to the found coordinates of FM and the known coordinates of the tetrahedron vertex $x_{V\,ENH}$, $y_{V\,ENH}$, $z_{V\,ENH}$ the volume of the unfilled part of fuel in the tank is determined by the formula :

$$
V_{\text{up}} = \frac{1}{6}\begin{vmatrix} x_{V\,ENH} & y_{V\,ENH} & z_{V\,ENH} & 1 \\ x'_1 & y'_1 & z'_1 & 1 \\ x'_2 & y'_2 & z'_2 & 1 \\ x'_3 & y'_3 & z'_3 & 1 \end{vmatrix} \qquad (11)
$$

The volume of the remaining fuel is found as the difference between the a priori known volume of the tetrahedron V_0 and the calculated unfilled part V_{up}.

The obtained solution of the fuel determination problem was considered in the *OENH* coordinate system. At the same time, in the conditions of a fixed base and during the aircraft evolutions, the position of the instrument triangle *OXYZ* will change in accordance with the changes in its angular position relative to the triangle *OENH*, i.e., with the changes in the angles of heading ψ, pitch ϑ, and roll γ of the aircraft. It follows that for finding the coordinates 1', 2', 3' of the FM intersection with the edges of the tetrahedron it is necessary to consider the inclination of the FM plane relative to the movable instrumental trihedral *OXYZ* (Fig.4).

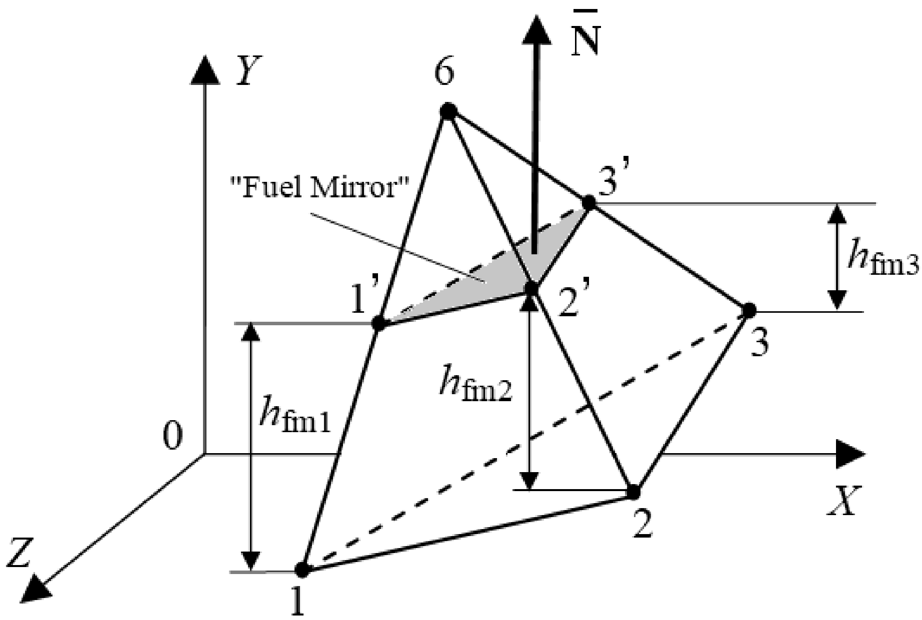

Fig. 3.3 Tilt of the "fuel mirror" plane relative to the movable instrumental trihedral

The relationship between the coordinates of the *OENH* triangles in *OXYZ* at the current moment of time can be found through the rectangular matrix of directional cosines

$$\mathbf{B} = L(\psi)L(\vartheta)L(\gamma) \qquad (12)$$

in the form

$$\mathbf{B} = \begin{bmatrix} \cos\psi\cos\vartheta & \sin\psi\sin\gamma - \cos\psi\sin\vartheta\cos\gamma & \sin\psi\cos\gamma + \sin\psi\cos\vartheta\sin\gamma \\ \sin\vartheta & \cos\vartheta\cos\gamma & -\cos\vartheta\sin\gamma \\ -\sin\psi\cos\vartheta & \cos\psi\sin\gamma + \sin\psi\sin\vartheta\cos\gamma & \cos\psi\cos\gamma - \sin\psi\sin\vartheta\sin\gamma \end{bmatrix}$$

In this case, the coordinates of the tetrahedron planes in the axes of the tetrahedron *OENH* will have the form

$$\begin{bmatrix} x_{V\,ENH} \\ y_{V\,ENH} \\ z_{V\,ENH} \end{bmatrix} = \mathbf{B} \begin{bmatrix} x \\ y \\ z \end{bmatrix} \quad (13)$$

The angles ψ, ϑ, and γ of the aircraft can be obtained from the inertial navigation system (INS), the heading and vertical system and other meters available on board.

In these cases, the FM plane at points 1',2',3' in the case of its inclination relative to the moving instrument triangle *OXYZ* is defined not by one vector perpendicular to the FM plane $N\{0, h_{fm},0\}$, as it was at zero heading angles ψ, ϑ, and γ of the aircraft, but by three vectors $\{0, h_{fm}1',0\}$ as it was at zero heading angles ψ, ϑ and γ of the aircraft, but three:

{0, hfm1', 0}, {0, hfm2', 0}, {0, hfm3′, 0}.

Thus, to calculate the heights $h_{fm}1'$, $h_{fm}2'$ and $h_{fm}3'$, it is necessary to have information from three HPS located at the vertices of the base of the tetrahedron (see Fig.4).

Thus, to solve the problem of determining the fuel residue in the mobile coordinate system at the current moment of time, it is necessary, in addition to the calculated values of $h_{fm}1'$, $h_{fm}2'$ and $h_{fm}3'$, to have information about the current coordinates of the vertices of the tetrahedron x_i, y_i, z_i and the coefficients of its planes $A_i, B_i, C_i, D_i \quad i=\overline{1...4}$ in the coordinate system *OXYZ*. These parameters at the current moment of time can be determined on the basis of the inverse matrix of directional cosines, obtained from the direct square matrix **B** through the known angles ψ, ϑ, γ:

$$\begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix} = \mathbf{B}^{-1} \begin{bmatrix} x_{i\,ENH} \\ y_{i\,ENH} \\ z_{i\,ENH} \end{bmatrix} \qquad (14)$$

$$\begin{bmatrix} A_i \\ B_i \\ C_i \end{bmatrix} = \mathbf{B}^{-1} \begin{bmatrix} A_{i\,ENH} \\ B_{i\,ENH} \\ C_{i\,ENH} \end{bmatrix} \qquad (15)$$

$$D_i = A_i x_{i0} + B_i y_{i0} + C_i z_{i0}; \qquad i = \overline{1...3} \qquad (16)$$

Based on relations (14) - (16) and calculated values of heights $h_{\text{fm}}1'$, $h_{\text{fm}}2'$, $h_{\text{fm}}3'$ according to the readings of three FMSs, the system of equations for calculating the coordinates of FM (8) … (10) in the axes of the moving trihedron *OXYZ* is as follows:

$$z'_{1_{XYZ}} = -\frac{A_2 D_{1XYZ} - D_{2XYZ} h_{\text{fm}}}{C_{1XYZ}}; \qquad (17)$$

$$x'_{1_{XYZ}} = \frac{h_{\text{fm}}(C_{2XYZ} - C_{1XYZ}) + C_2 D_{1XYZ} - C_1 D_{2XYZ}}{A_2 C_{1XYZ} - A_1 C_{2XYZ}};$$

$$z'_{2_{XYZ}} = -\frac{A_3 D_{2XYZ} - D_{3XYZ} h_{\text{fm}}}{C_{2XYZ}}; \qquad (18)$$

$$x'_{2_{XYZ}} = \frac{h_{\text{fm}}(C_{3XYZ} - C_{2XYZ}) + C_3 D_{2XYZ} - C_2 D_{3XYZ}}{A_3 C_{2XYZ} - A_2 C_{3XYZ}};$$

$$z'_{3_{XYZ}} = -\frac{A_3 D_{1XYZ} - D_{3XYZ}\, h_{\text{fm}}}{C_{1XYZ}}; \tag{19}$$

$$x'_{3_{XYZ}} = \frac{h_{\text{fm}}(C_{3XYZ} - C_{1XYZ}) + C_3 D_{1XYZ} - C_1 D_{3XYZ}}{A_3 C_{1XYZ} - A_1 C_{3XYZ}}.$$

Based on relations (12) and (14) … (19), the structure of the algorithm for determining the fuel residue at the current moment of time for a tank in the form of an arbitrary tetrahedron for a mobile aircraft can be represented as follows (see Fig.5).

3.2 Construction of the algorithm

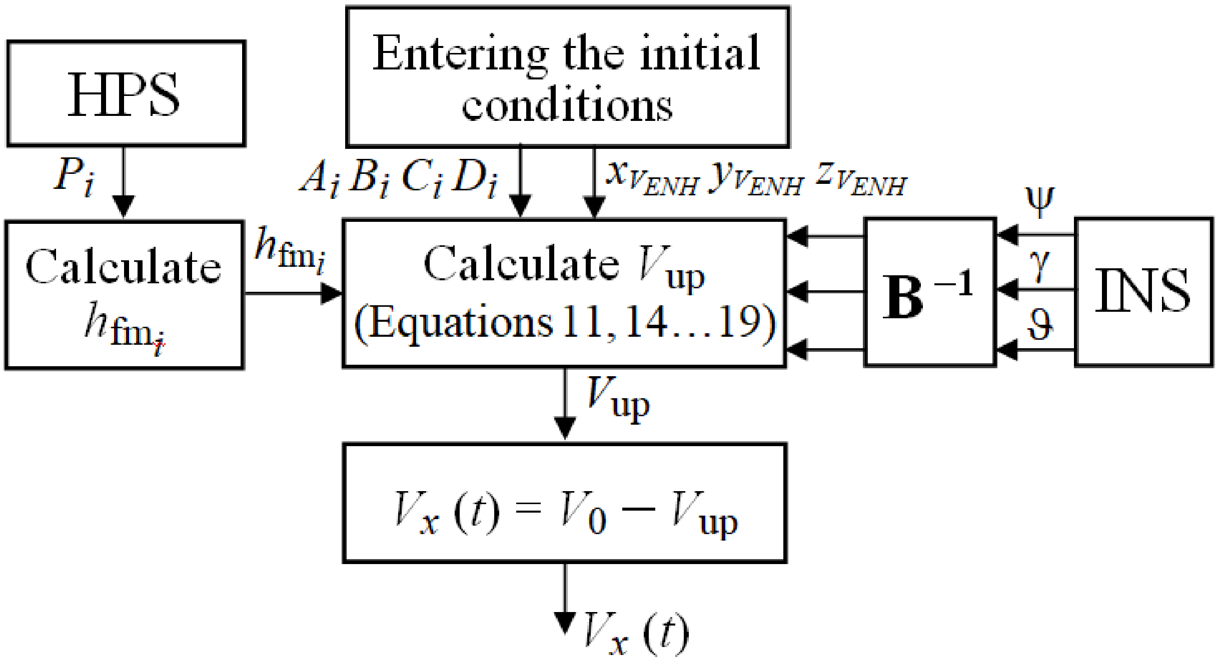

Fig. 3.4 Structure of the algorithm for determining the fuel residue at the current moment of time

When realizing the method of measuring the fuel residue in the tanks of aircraft with the division of tank volumes into tetrahedrons of arbitrary shape, there is a methodological error associated with the oscillations of the fuel surface at the occurrence of aircraft acceleration. For estimation of sensor measurements in the selected time interval of pressure measurement it is supposed to use methods of optimal measurement processing.

At mismatch of planes of tetrahedrons inscribed in the tank volume with real planes of tanks for compensation of methodical error the alignment is required. The alignment procedure can be realized by measuring by means of FMS the readings of current fuel consumption at change of heading angles ψ, ϑ and γ of the aircraft and comparing them with the real readings of fuel residue in the tank. The difference in readings can be considered in flight in the form of corrections coming from the calculator.

3.3 Conclusion

In this section, we allow the possibility of using a hydrostatic pressure sensor to accurately determine the remaining fuel in the aircraft tanks. The obtained results and studied aspects allow the use of key points that make this measurement method particularly effective in modern aviation technologies.

Advantages of using a hydrostatic pressure sensor:

- Measurement accuracy: Hydrostatic pressure sensors are characterized by high measurement accuracy, which allows you to get an accurate calculation of the remaining fuel in the aircraft tanks.
- Reliability: These sensors have a low probability of error and ensure stable and reliable operation even under different operating conditions.
- Possibility of use in different conditions: Hydrostatic sensors do not allow to measure the liquid level regardless of external factors, such as temperature or atmospheric pressure.
- Reduction of fuel costs: Accurate determination of the remaining fuel allows efficient use of resources and optimization of fuel consumption, which leads to a reduction of operating costs.
- Contribution to the stability of aviation operations: The use of hydrostatic sensors helps to reduce the risk of incorrect calculation of the remaining fuel, which can positively indicate the stability and sustainability of aviation operations.

The general essence of the studied aspects is that the use of a hydrostatic pressure sensor becomes a key element for accurate and reliable measurement of fuel remaining in aircraft tanks, because of which several tasks related to the operation of aircraft and optimization of their fuel consumption are solved.

CHAPTER 4

PROTECTION OF THE ENVIRONMENT

4.1 Life cycle assessment

Life cycle assessment (LCA) is a methodology for assessing the impact on the environment associated with all stages of the life cycle of a commercial product, process or service.

For example, in the case of an industrial product, the environmental impact is assessed from the extraction and processing of raw materials (cradle), through the production, distribution and use of the product to the processing or final disposal of the materials from which it is composed (disposal).

Life cycle assessment is one of the tools in the section [6] "Visual Data and Information (4.6.6 Visual Data And Information)», and is defined there as:

"This assessment is a tool used to determine the overall environmental impact of a product, process or system. It covers all aspects of the production of a project's output, from the origin of the materials used in it to its distribution and final disposal."

An LCA study involves a thorough inventory of the energy and materials required throughout the entire value chain of a product, process or service, and the calculation of the corresponding environmental emissions. Thus, life cycle assessment assesses the cumulative potential impact on the environment. The aim is to document and improve the overall environmental profile of the product.

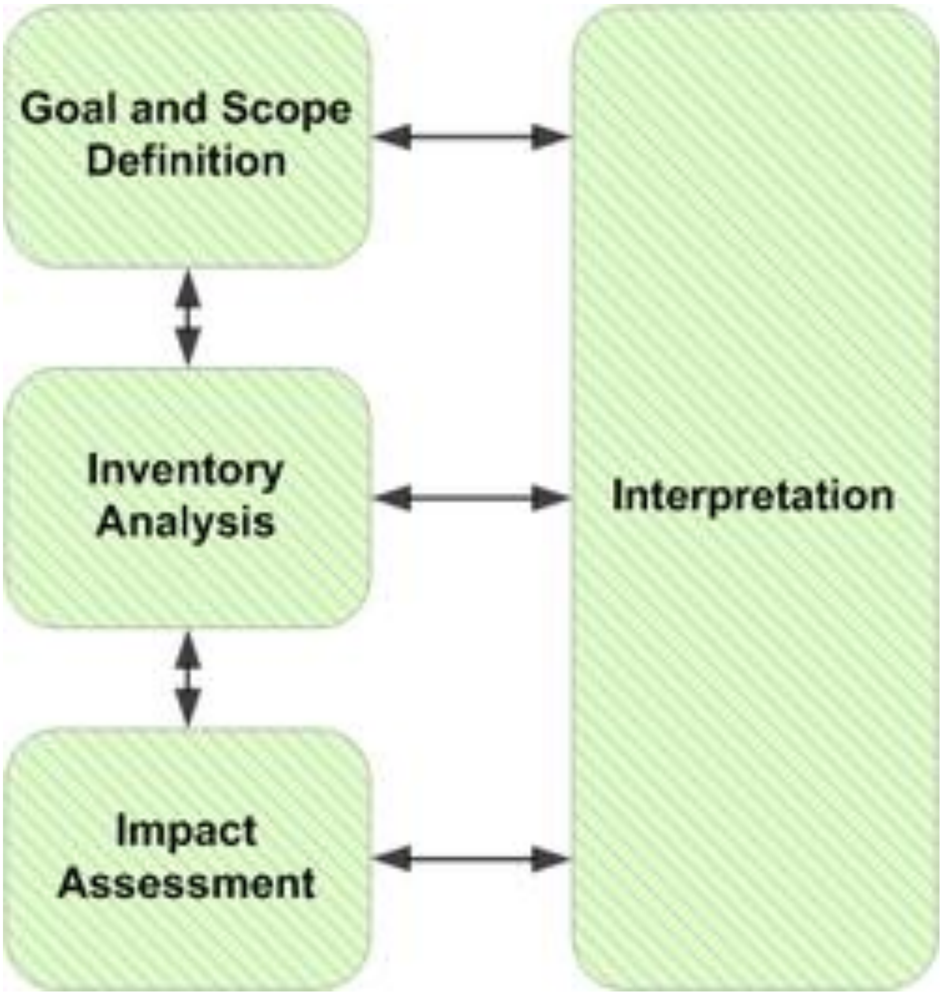

Fig. 4.1 Illustration of the general stages of life cycle assessment

Widely recognized LCA procedures are included in the International Organization for Standardization (ISO) 14000 series of environmental management standards, particularly ISO 14040 and ISO 14044.

ISO 14040 defines the "principles and structure" of the standard, while ISO 14044 contains a general description of "requirements and guidelines". In general, ISO 14040 was written for a management audience, while ISO 14044 was written for practitioners. In the introductory part of ISO 14040, the following definition of life cycle assessment is given:

LCA examines the environmental aspects and demonstrates the impact on the environment during the entire life cycle of a product (ie, quantity to grave) - from the procurement of raw materials to production, use and disposal. General categories of environmental impacts that require consideration include resource use, human health, and environmental impacts.

Definition, Synonyms, Objectives and Purpose of Life Cycle Assessment

Life Cycle Assessment - LCA is sometimes referred to as a synonym for life cycle analysis in scientific literature and agency reports. In addition, due to the general nature of LCA research, which takes place in the study of life-cycle impacts from raw material acquisition to disposal, it is sometimes referred to as "cradle-to-grave analysis".

According to the EPA's National Risk Management Research Laboratory, "LCA is a method of evaluating the environmental aspects and potential impacts associated with a product, process, or service by:

- Compilation of the inventory of relevant energy and material resources and emissions into the environment
- Assessment of potential environmental impacts associated with identified resources and emissions
- Interpretation of results to help you make a more informed decision."

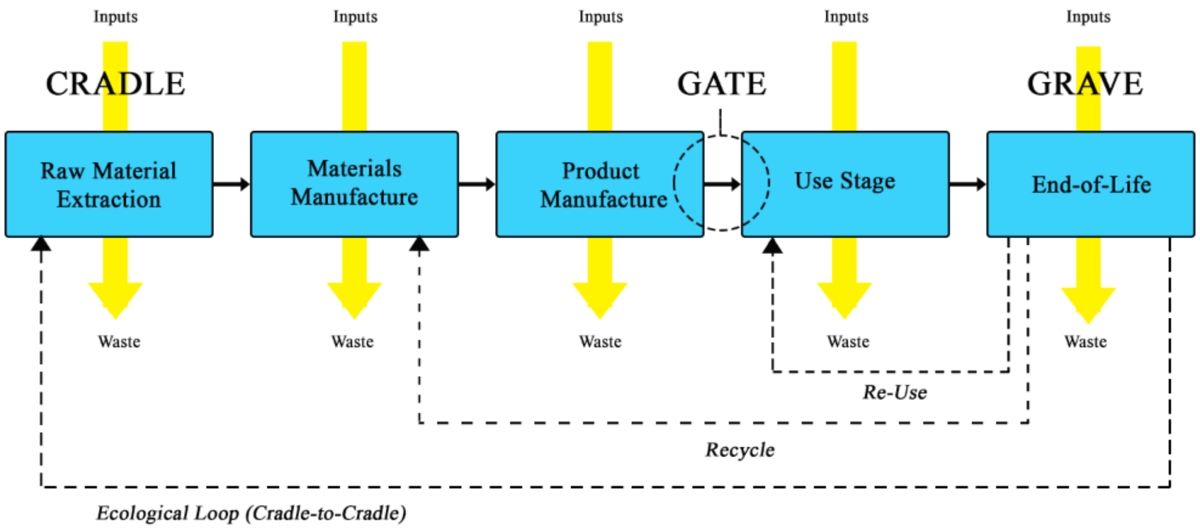

Fig. 4.2 An example of a diagram of life cycle assessment stages

Therefore, it is a method of environmental impact assessment related to all stages of a product's life cycle from raw material extraction to material processing, production, distribution, use, repair and maintenance, as well as disposal or recycling.

The results are used to help decision makers select products or processes that result in the lowest environmental impact by considering the entire product system and avoiding the suboptimization that would occur if only one process were used.

Thus, the purpose of LCA is to compare the full range of environmental impacts that may be inherent in products and services by quantifying all inputs and outputs of material flows and assessing how these material flows affect the environment. This information is used to improve processes, support policies and provide a reliable basis for making informed decisions.

The term "life cycle" means that a fair, holistic assessment requires an assessment of raw material extraction, production, distribution, use and disposal, including all intermediate stages of transportation necessary or caused by the existence of the product.

The main stages of life cycle assessment according to the ISO standard

According to [7] the ISO 14040 and 14044 standards, the assessment of the viability of objects consists of four separate stages. Stages are often interdependent in the sense that the results of one stage affect the completion of other stages. Therefore, none of the stages can be considered complete until the entire study is completed.

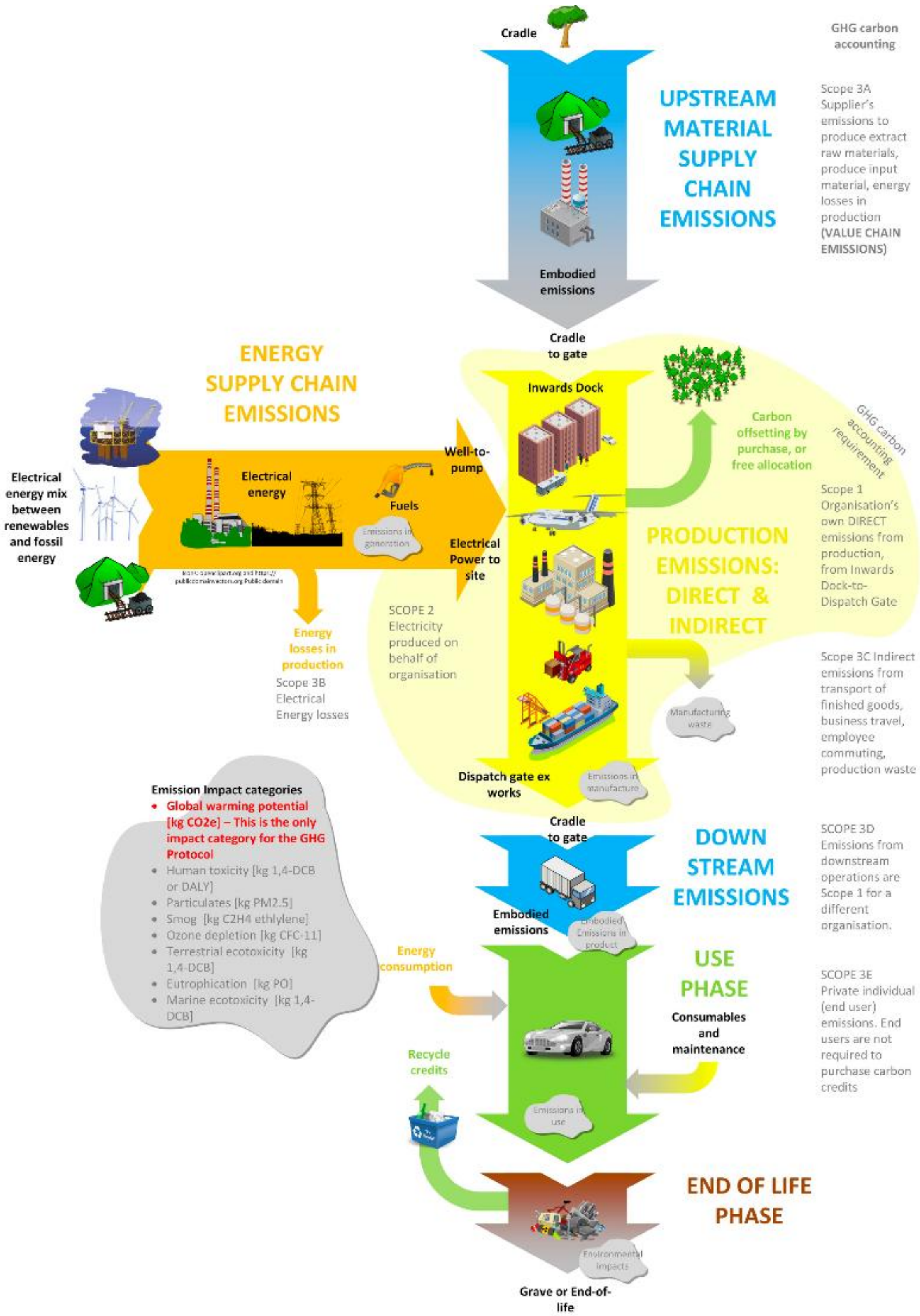

Fig. 4.3 Life cycle analysis and carbon accounting of greenhouse gas emissions

Description of the equipment in terms of the materials used

In aviation, various types of pressure sensors are used to measure the level of fuel in aircraft tanks. One type is hydrostatic sensors, which can be represented by different models and manufacturers. Let's consider the structure of hydraulic pressure sensors in general

4.2 The hydrostatic pressure sensor consists of several main components

Sensitive element: This is the main part of the sensor that responds to changes in pressure. It is usually a membrane or diaphragm that deforms under the influence of liquid or gas pressure.

Transducer: The part of the sensor that converts mechanical deformation (change in shape of the membrane or diaphragm) into an electrical signal. It can be a device based on the piezoelectric, capacitive or resistive effect, which generates an electrical signal proportional to the pressure.

Housing and protective elements: Sensors usually have a housing that protects sensitive elements from external influences such as moisture, dust and mechanical damage. Protective elements can include seals, filters and other components to ensure reliable operation in various operating conditions.

Electrical connections: Pressure sensors usually have connections to transmit a pressure signal to other systems or instruments in the aircraft so that pilots or automated systems can monitor fuel levels or other parameters.

4.2.1 Sensitive element materials

Stainless steel: It has high strength and corrosion resistance, making it a good choice for sensitive pressure sensor elements, especially where high environmental resistance is required.

Silicone: This material has good elasticity and can be used to create flexible sensitive elements. Silicone membranes or diaphragms are often used in sensitive sensor elements.

Ceramics: Some high-tech sensors use ceramic materials for sensing elements because of their strength, stability, and chemical inertness.

Titanium and its alloys: They can also be used to create sensitive elements, especially in cases where high strength is required with relatively low weight.

4.2.2 The transducer materials

Piezoelectric crystals: These crystals can be used to convert mechanical pressure into an electrical signal.

Metal diaphragms: Some pressure sensors use metal diaphragms that can change shape under pressure.

Semiconductor materials: Some transducers use semiconductor materials such as silicon.

Magnetoelectric material.

4.2.3 Corps materials

Stainless steel: It is often used because of its resistance to corrosion and high strength. Stainless steel is usually chosen for additional resistance to chemical environments.

4.2.4 Protective elements

Diaphragm: A diaphragm is used to interact with liquids or gases whose pressure is measured. Diaphragm materials can be ceramics, stainless steel, aluminum, polymers, etc.

Protective cover: A protective cover is sometimes used to protect the sensor from damage or contamination. A polymer can be used that allows pressure transfer but protects the internal components.

Protective membrane: In some cases where it is necessary to limit the ingress of liquids or particles, a protective membrane can be used. Its material may also include polymers or other resistant materials.

4.2.5 Electrical connections

Conductors: Cooper

Copper is one of the most used materials for conductors because of its high electrical conductivity and flexibility. It is often used for the manufacture of conductor cores.

4.2.6 Connectors and Contacts

Stainless steel: Stainless steel is a popular material for contacts and connectors because of its high corrosion resistance and strength. 316L stainless steel is a popular choice due to its chemical resistance.

4.2.7 Insulating materials

Thermoplastic polymers: Insulating sheaths of conductors made of high-strength thermoplastic polymers, such as polyvinyl chloride (PVC) or Teflon, allow to insulate the conductors and provide electrical safety and resistance to external factors.

4.3 Conclusion on all materials used in hydraulic pressure sensors

Metals: Stainless steel (e.g. 304, 316L) Titanium Brass Aluminum Bronze

Ceramics: Aluminum ceramics, Zirconium ceramics, Piezoelectric ceramics

Polymers (plastic): Teflon (PTFE) Polyethylene Polypropylene Polyurethane Polycarbonate

Specialized materials: Lightweight composite materials Cermet’s (alloys of ceramics and metals) Coatings and coatings for protection against corrosion and aggressive environments

Rubber and elastomeric materials: Silicone Fluorosilicone, Nitrile, Ethylene propylene rubber (EPDM)

Materials for sealing elements and membranes: Rubber, Polyurethane, Thermoplastic elastomers

4.4 The life stage of the production and manufacture of the hydrostatic pressure sensor

4.4.1 Extraction and processing of raw materials

Metal extraction: If the manufacturing sensor involves the use of metals (e.g. stainless steel, aluminum), the metal extraction process can have a significant impact on environmental emissions and impacts on the natural environment.

Production of polymers: if the production includes the use of plastics or other polymers, the process of producing polymers can be energy-intensive and associated with emissions of harmful substances.

4.4.2 Production of components

Energy-intensive processes: The production of individual components, such as the housing, diaphragm, or insulating materials, may require energy-intensive processes such as mold casting, thermoforming, or metal working.

Global transportation of raw materials: If components for a hydrostatic pressure sensor are manufactured on different continents or in remote locations, transporting raw materials can require a lot of energy and lead to increased CO_2 emissions.

Emissions of harmful substances: Some production processes may involve the use of chemicals that can be released into the atmosphere or water bodies, leading to pollution.

4.4.3 Assembly and testing

Energy use: Assembly and testing processes can require large amounts of electricity.

Waste disposal: Manufacturing may generate waste that needs to be disposed of or recycled to prevent negative impacts on the environment.

4.4.4 Packaging and Shipping

Efficient packaging: using environmentally friendly packaging materials and improving packaging methods can reduce costs.

The use of unequipped or inappropriate packaging during transport can damage products and create additional waste.

Transportation of the finished product: During the transportation of finished products, it may be necessary to use vehicles that use traditional energy sources and may emit pollutants.

Logistics management: Suboptimal logistics management can lead to excessive use of resources and CO_2 emissions due to redundant transport movements and reduced delivery efficiency.

4.4.5 Operation and maintenance

Need for spare parts: Transporting spare parts or components for service can also lead to increased emissions.

Need for maintenance: Hydrostatic pressure sensors may require periodic maintenance, including replacement of spare parts, cleaning, calibration and other maintenance procedures. Material and energy consumption is related to this.

Maintenance materials: The use of lubricants, cleaning agents and other materials during maintenance can affect the environment through possible emissions of harmful substances or production of waste.

Disposal of unusable products: If products do not meet standards or pass quality control, their processing and disposal may be included in the environment.

Power consumption: If the hydrostatic pressure sensor is mains powered, its operation will be associated with power consumption. This can affect the device's ability to be energy efficient and its impact on the environment, especially if the electricity is generated using non-environmental sources.

4.4.6 Replacement

Hydrostatic pressure sensors have a limited-service life, after which they may need to be replaced.

4.4.7 Utilization

Division into component parts:

The hydrostatic pressure sensor can be separated into its component parts for further disposal and recycling. This step allows materials and components to be separated for further use or recycling.

Sorting materials:

Different parts of a hydrostatic sensor can be made of different materials, such as plastic, metal, ceramic, etc. Sorting allows you to separate these materials for further disposal or processing according to their type.

Processing of materials:

Metal recycling: Metal parts can be recycled into shavings or secondary metal material that can be used in the production of new products.

Plastic recycling: Plastic components can be recycled to obtain secondary raw materials that can be used in the production of other plastic products.

Ceramic recycling: Ceramic materials can also be recycled or used in the production of new ceramic products.

Safe disposal and disposal of waste:

Disposal of hazardous substances: If the hydrostatic pressure sensor contains hazardous substances, such as batteries or electronic components, they must be removed and disposed of in a safe manner.

Safe disposal: Residues and non-recyclable materials must be safely removed and disposed of in accordance with environmental standards.

Promotion of secondary use:

Use of secondary raw materials: The specified materials after processing can be used for the manufacture of new products, which contributes to the concept of secondary use and reducing the use of primary resources.

Environmental standards:

Compliance with environmental standards: Disposal must comply with current environmental standards and regulations to minimize negative impact on the environment.

4.5 Comparison with Piezoelectric pressure sensor

4.5.1 Use of materials

Hydrostatic sensors: usually made of minor substances such as metals and rubber that do not contain toxic substances.

Piezoelectric sensors: Crystals such as quartz are used, which may include some chemicals or processing that may be less environmentally friendly.

4.5.2 Power sources

Hydrostatic sensors: many of the hydrostatic sensors can operate directly without their own power source, which can reduce environmental impact.

Piezoelectric sensors: some piezoelectric sensors may require a power source to generate electrical energy.

4.5.3 Production and removal

Hydrostatic sensors: usually have a simple design and are made of materials that are easily recycled and removed.

Piezoelectric sensors: the manufacture of crystals and other components may involve processes that are more energy intensive and may be less environmentally efficient.

Considering these aspects, hydrostatic pressure sensors can be more environmentally friendly in many scenarios.

4.5.4 Recommendations for limiting exposure

Reducing the environmental impact of hydrostatic pressure sensors can be achieved through several strategies and practices

Choosing environmentally friendly materials: Choose materials for the manufacture of the sensor that do not contain toxic substances or materials that can be easily recycled.

Production optimization: Reduce the use of resources and energy during sensor production. Use technologies and processes that reduce emissions and waste.

Design improvements: Develop sensors with efficient and energy-saving designs. Reduce the number of components and heavy metals used in the sensor.

Use of renewable energy resources: If the sensor requires power, consider using renewable energy sources such as solar panels or the energy of natural fluid motion.

Easy reprocessing and disposal: Designing the sensors in such a way that they can be easily disassembled and recycled in the result. Provide disposal instructions so consumers know how to properly dispose of sensors without harming the environment.

Encouraging recycling: Development of a collection and recycling system for used sensors to reuse materials and reduce waste.

Improving energy efficiency: Optimize the energy consumption of sensors during their operation.

Ecolabelling: Providing information to users about the environmental friendliness of your product so that consumers can make an informed choice.

4.6 Conclusions

The section examines the hydrostatic pressure sensor and establishes that it can be considered relatively environmentally friendly, as they are usually made of materials that do not contain toxic substances. Such sensors can be used to measure pressure in various media, be it liquids or gases. One of the advantages of hydrostatic sensors is their lack of need for a power source in many cases, which reduces environmental impact and promotes energy efficiency.

In addition, optimization of the manufacturing process, use of environmentally friendly materials and balanced design can contribute to the reduction of waste and emissions during the production and operation of hydrostatic sensors. In addition, the possibility of easy recycling and disposal ultimately makes them less impactful on the environment.

CHAPTER 5
LABOR PROTECTION

5.1. Organization of the workplace of a specialist engineer

Engineers who install hydraulic sensors on aircraft tanks usually work in specialized aviation centers or airline maintenance departments. It can also be a room where aircraft repair, maintenance and service work is carried out.

The room intended for the engineer must be equipped with the technical means and equipment necessary for the installation and maintenance of hydraulic converters. Workspaces may include special tables for setting up and adjusting equipment, workspaces for access to the aircraft, and storage spaces for tools and technical documentation.

It is also important to consider the requirements and safety regulations specific to the aviation sector. Work areas must be kept clean, and equipment properly maintained and calibrated. Engineers may also have access to technical laboratories and facilities for testing installed equipment.

The engineer's workplace here is a place where specialized technical activities are carried out, the organization of which is determined by requirements for technical equipment, accessibility to aircraft and compliance with aviation safety standards.

It is important to provide a safe and organized work environment. Equip workplaces in accordance with aviation safety standards and separate access areas and work areas. Maintain cleanliness and have all necessary tools and equipment.

Provide engineers with all necessary personal protective equipment (PPE), including protective clothing and gloves, and adhere to all safety requirements for working in the aviation industry.

Consider all the requirements of the technical documentation and drawings and ensure free access to the tanks of the aircraft and the locations of the pressure sensors. Make sure the hydraulic sensors are properly calibrated and installed correctly.

Communicate effectively with other crew members and technical personnel. Use antistatic products to prevent static electricity.

Follow the safety requirements and manufacturer's instructions. It is important that the technical personnel are properly trained and have relevant experience in working with aviation equipment.

5.2. Analysis of risk factors at the workplace

Engineers who install hydraulic sensors on aircraft tanks face dangers and risks related to the nature of the task and the characteristics of the aircraft equipment. Let's consider some of the possible dangers.

5.2.1 High pressure and hydraulic systems

The use of high pressure and hydraulic systems is particularly challenging in the aviation environment and requires high safety standards. Let's consider some considerations in this regard:

[8] DSTU EN 13306:2019 "Means for maintaining technical compatibility and information exchange. Terms and definitions" define the terms and definitions related to means for maintaining technical compatibility and information exchange. This standard can be important to ensure interoperability between different hydraulic systems and high-pressure measuring devices in complex technical environments, particularly in the aviation industry.

The use of high pressure in hydraulic systems may require not only technical compatibility between components, but also effective methods of sharing information regarding the safety and reliability of these systems. Adherence to the standards defined by DSTU EN 13306:2019 can contribute to improving the safety and functionality of hydraulic systems, reducing risks and ensuring a high level of reliability in the aviation environment.

Risk of hydraulic fluid leakage: Working on hydraulic systems may result in hydraulic fluid leakage due to accident or damage. Since hydraulic fluid is flammable and toxic, engineers must be prepared for the risk of a possible leak and know the measures to immediately eliminate it.

Overpressure and accidents: When installing pressure sensors, engineers must ensure that the specified pressure parameters are met and that the hydraulic system is operating within normal limits. Excessive pressure can cause accidents, destruction or damage to equipment.

Special tools and safety equipment: The engineer must use special tools and equipment to work with the hydraulic system and ensure safety. These include hydraulic pumps, pressure reducers and protective equipment such as gloves and protective clothing.

Constant attention to detail and craftsmanship: The use of hydraulic systems requires attention to detail and a high level of craftsmanship. Engineers must have experience working with hydraulic equipment and have a good understanding of its principles of operation.

5.2.2 Work at Height

Engineers may encounter situations where they must work at heights or on aircraft. In such cases, there may be a risk of accidents and injuries when using the equipment at height.

DSTU EN 361:2017 "Individual equipment for protection against falls from a height. Equipment for the whole body" establishes requirements for personal equipment intended for protection against falls from a height. This standard is mandatory for use in situations where engineers must work at height or in conditions where there is a potential risk of falling.

According to DSTU EN 361:2017, personal fall protection equipment must be designed and manufactured to provide effective protection and ease of use. This equipment covers all parts of the body and provides restraint in the event of a fall, minimizing the risk of injury and providing workers with an appropriate level of safety when working at heights or on aircraft.

Safety of equipment at height: It is important that equipment that engineers may use at height, such as machines, leaders, and other platforms, is inspected and maintained in a safe condition. Improper use or repair of the equipment can lead to danger.

Installation Safety Requirements: When installing hydraulic transmitters at height, engineers must follow all safety requirements and installation standards. This includes ensuring that equipment is properly secured and protected from falling objects, as well as compliance with work at height regulations.

Working hours and physical condition: working at height requires prolonged exposure to heights. This can cause physical fatigue and stress, so engineers must be in good physical shape and manage their time resources accordingly.

Climatic conditions: Working at height can expose engineers to dangerous climatic conditions such as strong wind, rain, snow and cold. It is important to take appropriate safety precautions to prepare for changing weather conditions.

Training and education: Engineers must have the appropriate training and skills to work safely at height. This includes knowledge of emergency evacuation procedures, use of protective equipment, and the ability to work effectively in high-risk environments.

5.2.3 Electronics and Electrical Components

Engineers must also work with electrical and electronic components. Contact with electronic equipment may pose a risk of electric shock and damage to electronic systems.

According to DSTU 7237:2011 "System of occupational safety standards. Electrical safety. General requirements and nomenclature of types of protection", engineers are obliged to comply with all electrical safety rules. This standard establishes general requirements and a nomenclature of types of protection that must be applied to ensure safety when working with electrical systems and equipment. In particular, engineers must use insulated tools, properly disconnect power before starting work, and avoid contact with live wires to prevent adverse effects such as electric shock and equipment damage.

Grounding and static electricity: When working with hydraulic equipment containing electrical components, static electricity can be generated. Engineers must follow grounding procedures to prevent static electricity from building up and affecting electronic equipment.

Interaction with electronics: When working with electronic components, they can interact with avionics. Engineers must be familiar with the characteristics of these systems, follow the manufacturer's instructions, and use antistatic agents to prevent damage.

Accuracy and Calibration: When installing hydraulic transducers with electrical components, accuracy and proper calibration must be ensured. This requires additional electronics settings to ensure correct pressure measurement.

Compliance with electrical standards: Engineers must work in accordance with electrical standards and regulations related to avionics. This includes correct wiring, use of appropriate materials and compliance with electrical safety requirements.

Safety from interference: Engineers must ensure that this does not affect the operation of other electronic systems on the aircraft and consider the possibility of electromagnetic interference. This may require shielding and isolation measures.

5.2.4 Chemical substances

Engineers must also work with electrical and electronic components. Contact with electronic equipment may pose a risk of electric shock and damage to electronic systems.

According to DSTU 7237:2011 "System of occupational safety standards. Electrical safety. General requirements and nomenclature of types of protection", engineers are obliged to comply with all electrical safety rules. This standard establishes general requirements and a nomenclature of types of protection that must be applied to ensure safety when working with electrical systems and equipment. In particular, engineers must use insulated tools, properly disconnect power before starting work, and avoid contact with live wires to prevent adverse effects such as electric shock and equipment damage.

Hydraulic Fluids: Many aircraft use hydraulic systems to control moving parts. Hydraulic fluids such as oil-based hydraulic fluids and synthetic oils can react chemically. Some of them can be toxic or inflammatory. Engineers must consider these properties and use appropriate protective equipment to prevent skin contact and inhalation of vapors.

Refrigerants: Some systems may use refrigerants to regulate temperature. These fluids may contain chemical additives to prevent freezing and oxidation. Engineers must be aware of potential risks and take precautions.

Lubricants: Some hydraulic system components may require lubricants. These substances can be chemically active. Correct selection and use of lubricants is important to ensure efficient operation and service life of the system.

Skin and Eye Protection: To prevent contact with chemicals, engineers must use appropriate skin protection such as gloves and clothing, as well as safety glasses, as splashes of liquid may enter the eyes.

Proper storage and disposal: The proper storage and disposal of chemicals is important to prevent potential accidents and ensure compliance with environmental standards. Technical personnel must follow the manufacturer's instructions and relevant legislation.

Instructions for use and safety precautions: Engineers should read the manufacturer's instructions for use of the chemicals they use. It is also important to follow all the safety measures described in the instructions.

5.2.5 Technical Specifications

Incompatibility with technical requirements and non-compliance with safety standards can lead to incorrect installation of equipment, which will eventually lead to a serious accident.

Compatibility and Suitability: Engineers must ensure that the hydraulic transducers they install are fully compatible with the specific aircraft and hydraulic system. They must also meet all specifications and standards established by the aircraft manufacturer and the relevant aviation regulatory authorities.

Accuracy and Calibration: Specifications of a hydraulic sensor include its accuracy and calibration capabilities. Engineers must ensure that each sensor is properly configured to measure pressure according to specification.

Pressure and temperature: it is important to observe the specified technical parameters of working pressure and temperature. Based on the specifications, engineers must ensure that the sensors and hydraulic system can withstand the expected loads.

Materials and durability: the specifications contain information about the materials from which the sensors and other system components are made. This is important to ensure durability and resistance to corrosion and other influences.

Electrical characteristics: If hydraulic sensors have electronic components, engineers must consider electrical characteristics such as supply voltage, power consumption and other parameters to ensure proper connection and use.

System requirements and compatibility: technical specifications must meet the system requirements of the equipment and its compatibility with other components of the hydraulic system. This is important to ensure the integration of new equipment and interfacing with existing aviation equipment.

Manuals and Technical Documentation: Engineers should have access to most manuals and technical documentation specified by the hydraulic equipment manufacturer. This will ensure correct understanding and compliance with technical requirements.

5.3 Analysis of risk factors at the workplace

5.3.1 Stress and work pressure

Although there is potential danger in every aspect of working with hydraulic systems, stress is one of the most dangerous factors for workers. Stress can arise from various sources and affect the physical and psychological health of the employee.

Physical and mental health:

Stress can cause a number of problems with physical and mental health. Physical symptoms of stress include fatigue, muscle pain, and neuralgia. Mental stress can cause anxiety, depression and decreased cognitive function.

Health and Safety Risks: Stress can increase the risk of workplace injuries and accidents. It can reduce concentration at work, leading to errors and poor judgment, especially when working with hydraulic equipment.

Reduced productivity: Prolonged stress can lead to worker fatigue and reduced productivity. Decreased productivity can be a major factor in machine-related work where precision and attention to detail are important.

Misunderstanding: Stress can affect the effectiveness of communication between employees. When installing hydraulic sensors, misinterpretation or misunderstanding of information can lead to errors and accidents.

Risk of depression and burnout: Prolonged stress can contribute to the development of depression and burnout in employees. This can have serious consequences for the quality of work and the general state of health of the employee.

Health and Safety Effects and Features of Work: Working with hydraulic systems often requires a high degree of attention and precision. Stress can create situations where workers cannot concentrate on complex tasks, which can lead to accidents and injuries.

In order to improve the working environment and remove stress factors, it is recommended to implement individual and group strategies. Psychological support programs, stress management training, as well as special measures to increase the adaptability of employees can contribute to the relief of psychological pressure.

Ensuring workers are trained in the safety and efficient use of hydraulic equipment also plays a key role in preventing injuries and accidents. It is important to encourage a culture of safety and open communication between employees and management.

The introduction of periodic checks of the condition of the equipment and its technical serviceability can reduce the risk of accidents. Additionally, developing emergency response procedures and training employees to act in stressful situations is an important element of improving overall safety in the workplace.

In summary, a comprehensive approach to the management of stress factors and workplace safety includes organizational, psychological and technical measures aimed at ensuring safe and effective work with hydraulic equipment.

5.4 Fire Security

In the field of fire safety, it is important that engineers pay special attention to a number of aspects to ensure safe operation and minimize the risk of fire.

Fig. 5.1 Fire safety

First, engineers must have a good understanding of fire safety and be aware of the potential hazards associated with their work. They must know how to use fire extinguishers correctly, where emergency exits are located, and how to work effectively with fire protection systems.

Another important point is interaction with electrical equipment and systems. Engineers must practice electrical safety, avoid overloading, and use electrical equipment with due care.

Special attention should be paid to the use of fire-fighting materials. Engineers must know how to use flame retardant materials correctly and how they interact with other plant components.

Proper storage and handling of combustible materials is an important part of an engineer's job. It is necessary to follow the rules and standards for the storage of volatile and flammable materials in order to avoid fire-hazardous situations and unpredictable reactions.

In addition, engineers must be ready to act in emergency situations. Regular drills, including evacuation procedures and the use of firefighting equipment, help maintain calm and efficiency in dangerous situations.

All these measures are aimed at creating a safe working environment for engineers and ensuring the highest level of protection against fire hazards.

5.5 Organizational and technical measures to combat harmful and dangerous factors

Organizational and technical measures are recommended to reduce stress in the workplaces of engineers. They include the development of psychological support programs for employees and the creation of appropriate working conditions with flexible schedules and comfortable conditions. Technical measures include the use of modern technologies to monitor physiological parameters and establish ergonomic workplaces.

It is also important to conduct stress management training that focuses on the use of self-regulation and relaxation techniques. Educating employees and raising their awareness of stressors can help them develop a conscious approach to their own well-being.

At the same time, it is important to create support structures in the organization and establish effective interactions between colleagues to help them cope with stressful situations. Creating a positive work environment where teams support each other and develop a collaborative approach to problem solving can significantly reduce stress levels and improve overall employee well-being.

5.6 Conclusion

After analyzing the working conditions of engineers who install hydraulic sensors on aircraft tanks, it can be concluded that the workplace depends on an adequate level of safety and organizational and technical training. However, there are also a number of potential threats, such as the importance of proper installation and operation of hydraulic sensors, lack of time and the possibility of stressful situations.

The analysis shows that the productivity and safety of engineers can be improved by implementing a number of measures. The development of psychological support programs and stress management training are especially important. Technological innovations such as physiological monitoring and ergonomic equipment can also make a significant contribution to improving working conditions.

Next steps include implementing recommendations to improve organizational and technical aspects of safety, ensuring regular updates of safety programs and paying more attention to the psychosocial well-being of employees. Overall, these measures are aimed at providing a safe and productive work environment for engineers.

CONCLUSION

In the course of the diploma work, a detailed study and analysis of the problem of efficient use of fuel in the aviation sector, in particular in the event of a landing delay, was carried out. Taking into account the significant increase in the cost of aviation fuel, the emphasis was placed on the development of a system for assessing the fuel balance to optimize its use and ensure the efficiency of aviation transport.

As a result of the work, a hydrostatic pressure sensor was implemented as a key component of the system to obtain accurate and reliable data on the remaining fuel in the tanks during flight. The use of this sensor allows you to ensure high accuracy of measurements and reduce the possibility of errors in calculations.

The system for estimating the remaining fuel in the event of a landing delay was developed taking into account the requirements for the efficient use of fuel in conditions of high costs and an increase in its cost. This system not only contributes to fuel economy, but also ensures flight safety and increases the overall efficiency of air transport.

Therefore, the developed system turns out to be an important step in the direction of optimizing fuel consumption and ensuring effective management of resources during a landing delay. Taking into account the current trends in the field of aviation, its implementation can lead to an improvement in the economic efficiency of air transportation and a reduction in the impact on the environment.

The following were performed in the process task:

1. The relevance of the topic has been proven and the goal and task have been set.

2. The considered structure of the aircraft tank

3. The existing sensors for measuring fuel in aircraft tanks were analyzed

4. An algorithm for calculating the remaining fuel using a hydrostatic pressure sensor was developed

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