SMART RUNWAY: AN INNOVATIVE SOLUTION TO INCREASE THE SAFETY OF THE AVIATION INDUSTRY

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Abstract

The aim of the current research was to investigate the innovative solution to increase the safety of the aviation industry by using artificial intelligence capabilities. In this research, the evaluation of the capabilities of artificial intelligence in the infrastructure and control of the airport runway to solve the problem of slippage during landing and take offs, as well as the construction and control of the moving Ford carriage during the Ford emergency was discussed. The results of the current research showed that artificial intelligence can detect runway slippage by using data from runway sensors and weather data and help pilots take the necessary measures to land the plane safely. Predict runway slippage in the future using historical data and weather forecast data. Also, artificial intelligence can help in designing a mobile landing gear more optimally and safely and controlling it automatically and safely. As a result, AI can identify potential hazards using various data, such as radar data, weather data, and runway performance data. It can help air traffic controllers take necessary actions to prevent accidents and can automate some air traffic control tasks. This can help reduce the workload of air traffic controllers and improve safety.

Keywords: commercial aircraft, artificial intelligence, airport runway, landing gear, traffic control, runway slippage, air accidents.

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1. Introduction

In recent years, due to the economic, industrial and social developments of the countries of the world, the importance of moving passengers and cargo has increased significantly. Among all transportation systems, air transportation is the most popular, safest, and most advanced system, so that today, an advanced and precise aviation system can be directly related to having a successful society [2]. With the expansion of the air transportation system, the increase in the number of airports and equipment, and improvements in the design and production of airplanes, it can be said that daily thousands of passengers and hundreds of tons of cargo are moved between cities, countries and even continents by small and large airplanes. are [3]. Like any other man-made device, airplanes have had a large number of catastrophic accidents that have resulted in countless human deaths and huge financial

damages, and even in a few cases, these events have led to social crises. Aviation events have a wide range; From a tire burst to the crashes and collisions of two planes are classified in the field of aviation accidents [1]. Today, a competitive environment has emerged between people, and this environment has caused people to seek progress and simplify things day by day. Today, airline companies and researchers spend a lot of resources such as money, time and manpower to prevent these unwanted events from happening or to reduce their rate of occurrence; According to what was said, the investigation of air accidents and accidents should continue continuously [4].

Different airlines have always been trying to expand their operations and be better compared to other companies. Also, in terms of safety, it is a reliable company for customers to choose in order to make their name known to the world in addition to generating a lot of income [2]. The aviation industry is a dynamic and ever-evolving sector. As technology advances and becomes more complex, the aviation industry must keep pace with changing trends. The aviation industry has undergone a huge transformation with the advancement of technology and the development of new digital capabilities. Smart solutions can increase effectiveness, reduce costs and increase productivity in the industrial sector. Advanced systems integrate a variety of advanced technologies including automation, robotics, artificial intelligence (AI), machine learning, mixed reality, and the Internet of Things (IoT) [5, 6, 7] Digitization has changed the paradigm of the intelligent aviation industry. Innovative digital approaches recently promote efficiency, safety and security in the operational process and increase passenger satisfaction by better understanding their needs, preferences and habits [8]. Digitalization has increased collaboration and communication between airlines, airports and other aviation stakeholders [9]. With machine learning and mixed reality, the aviation industry has the chance to revolutionize aerospace engineering and enhance the passenger experience [2].

Artificial intelligence is one of the things that has attracted the attention of many engineers and researchers. By combining artificial intelligence and the aerospace industry, engineers have been able to simplify many of today's challenges. Although this sector still has a lot of work to do; But if it reaches its ideal level, great progress will be achieved in the world and it will change many daily tasks and make things easier [10]. With its vital role in the technology industry, artificial intelligence simulates the processes of human intelligence by using machines and computer systems to obtain information, solve problems, and draw conclusions. Experts who work in the aviation industry say that the use of artificial intelligence can increase speed, efficiency and safety, and have many effects on complex technologies. Therefore, the use of artificial intelligence in different parts is one of the options that can make companies progress. Although artificial intelligence in various industries, especially in the aviation industry, is still in the initial stage, but companies have put a huge and significant part of their capital as well as their skilled employees to focus on this sector, and therefore many improvements have been made [11]. Artificial intelligence has wide applications in airports that help improve efficiency, security and passenger experience. Among others, it helps in facial recognition and biometrics, security and threat detection, baggage handling, predictive maintenance, passenger assistance and chatbots, optimization of cargo transportation and airport operations [12].

However, AI may be able to go far beyond current applications. It should be noted that today, leading airlines are exploring how artificial intelligence enables them to keep pace with customer demand and improve operational quality, speed, and customer loyalty [11-12]. Many experts believe that the use of artificial intelligence technology can reduce the cycle of the aviation industry, especially air accidents, because the investigation of various causes in air accidents and the factors that cause them and with regard to the invention and creation of various monitoring tools inspection, these accidents can be prevented as much as possible or

possible damages can be minimized [3]. One of the most famous techniques used in this field is the use of artificial intelligence tools that can be used in the processes of predicting and preventing all kinds of accidents and air accidents and dealing with them in a planned way [13]. Therefore, artificial intelligence has made our world smarter and continues to permeate various fields. The aviation industry is one of the areas where the tendency to use modern technologies, including artificial intelligence, is increasing, and its results have been observed in airports and air travel to some extent [14]. Based on this, in the current research, the application of artificial intelligence in the field of airport runway infrastructure to solve the problem of slippage during snow and rain and the use of this technology in the construction of mobile landing gear during the transfer of aircraft landing gear are discussed.

2. Research literature

2.1. Artificial intelligence

Despite its widespread use, artificial intelligence is a complex concept that has no single, simple definition. Researchers like Hamet and Tremblay and Kaplan and Haenlein have provided a hybrid definition, describing artificial intelligence as a set of algorithms that can mimic human intelligence to a certain extent. These algorithms can interpret, analyze, and suggest solutions based on the data provided, without explicit programming. Artificial intelligence encompasses various branches, each with its own set of applications [13, 14]. As shown in Figure 1, machine learning, computer vision, and natural language processing (NLP) stand out as some of the most well-known applications of artificial intelligence. These applications are relevant in various fields, fields such as medicine, monitoring, transportation, pricing, operations, military applications and intelligent enterprise planning. In several studies, the term "AI" is closely related to other terms such as "Big Data Technologies (BDT)", "Machine Learning (ML)" or "Intelligent Analytics" [15]. While scholars may disagree on the exact terminology of these concepts, there is consensus that data as a common currency connects them all [16].

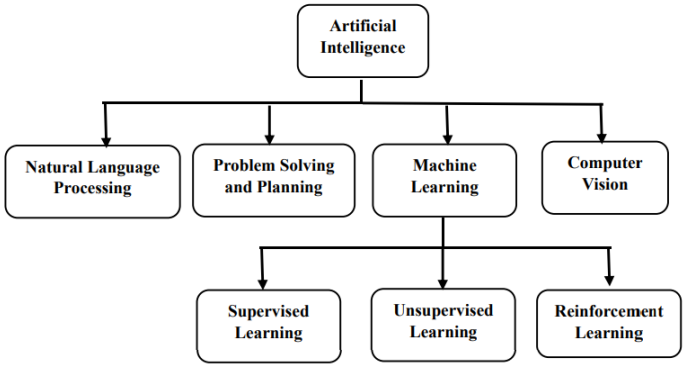

Figure 1. A summarised view of the various concepts contained within Artificial Intelligence [23].

Algorithms used to develop intelligent systems vary widely in terms of complexity, suitability and field of application. Although most of these algorithms are supervised by machine learning, they are still a subset of artificial intelligence [23]. With the variety of problems, we face today, it can be assumed that there is no one-size-fits-all solution. With this perspective, ML algorithms are usually classified into 3 main paradigms: supervised, unsupervised and reinforcement learning. The desired result and the type of available data control the range of techniques that can be used [24]. Figure 2 provides an overview of these different ML techniques.

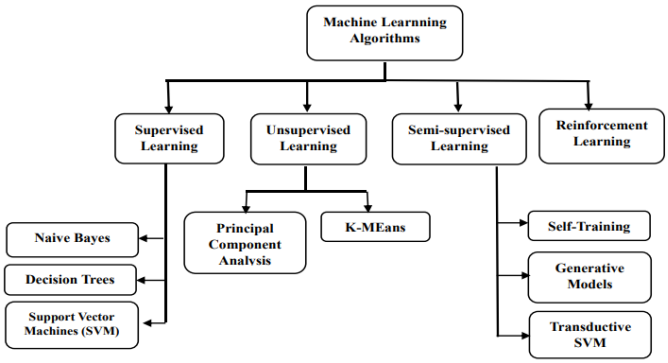

Figure 2. Most prominent machine learning algorithms and their subcategories [25].

2.2. Artificial intelligence in the aviation industry

The aviation industry has undergone a huge transformation with the advancement of technology and the development of new digital capabilities. Smart solutions can increase effectiveness, reduce costs and increase productivity in the industrial sector. Advanced systems integrate a variety of advanced technologies, including automation, robotics, artificial intelligence (AI), machine learning, mixed reality, and the Internet of Things (IoT) [22]. Digitization has changed the paradigm of the smart aviation industry. Innovative digital approaches recently improve efficiency, safety and security in the operational process and increase passenger satisfaction by better understanding their needs, preferences and habits [12]. Digitization has increased collaboration and communication between airlines, airports and other aviation stakeholders [30]. With machine learning and mixed reality, the aviation industry has the chance to revolutionize aerospace engineering and enhance the passenger experience [26]. Machine learning is critical to digitize, interpret and identify features, patterns and trends in digital data to gain valuable insights and make informed decisions [14]. Machine learning provides powerful tools to create efficient, reliable and safe aircraft design, manufacture and training. Applications of machine learning in digital twins, aerospace design, aerospace manufacturing, aerospace verification and validation, and aerospace services have increased automation and simplified processes in the aerospace industry [5]. Transformative machine learning using digital modeling and simulation impacts manufacturing, automation and data analysis in the aerospace industry [6].

The data-rich aviation industry is poised to capitalize on the machine learning revolution. Machine learning optimizes transportation networks, predicts customer behavior, and provides tailored services to improve the passenger experience. Airlines can optimize operations, improve loyalty and increase revenue by analyzing passenger data [9]. Machine learning tracks and analyzes multiple stages of passenger transit, including arrivals, departures, and waiting periods to reduce delays and improve the customer experience. Airlines use mobile apps to provide real-time updates and personalized service. Smart services such as customized tickets, baggage tracking and flight tracking are provided by airlines [13]. Machine learning is a useful technology that makes traveling more enjoyable and enjoyable [26]. Mixed reality can be applied to aviation through a combination of robotics, analytics, mobility and visualization. Mixed reality has the potential to revolutionize aerospace engineering [19]. Using mixed reality, aerospace engineers can easily develop virtual worlds where they interact with physical objects in a realistic way [11].

With the growth of the aviation industry, the demand for affordable and high-quality aircraft parts has increased. To meet this need, aircraft companies are looking for innovative ways to design aircraft parts. Artificial intelligence, especially machine learning, can help aircraft companies in this area. Machine learning can help aircraft companies design aircraft parts in a number of ways. For example, machine learning

can be used to identify patterns in historicaldata so that engineers can design parts that perform better while being more cost-effective. Machine learning can also be used to simulate the performance of real-world aircraft components so that engineers can design components that are safe and reliable. Regarding the size of the aircraft, engineers must ensure that the aircraft is large enough to carry cargo and passengers. However, the size of the aircraft also affects fuel consumption and performance. Machine learning can help engineers optimize aircraft size to meet performance and economic needs. In the past, traditional mathematical models were used to simulate the performance of aircraft. However, these models were often notsufficiently accurate. Machine learning can help with this problem by providing models that are more accurate. All inall, artificial intelligence, especially machine learning, can help aircraft companies design aircraft parts in a number of ways. This technology can help aircraft companies design parts that are more cost-effective, safer and more efficient [4].

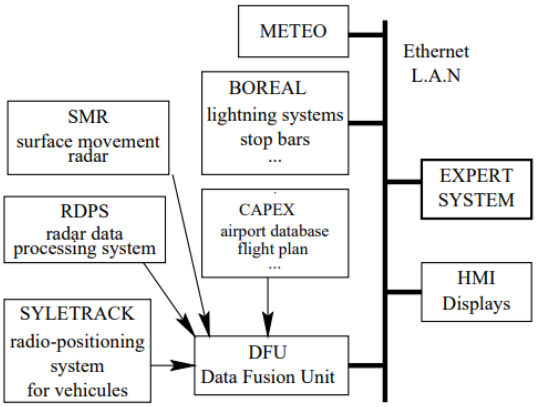

Figure 3. Overview of the whole system[26]

The aviation sector has benefited from technological innovations that have helped connect it to the global economy and empower other industries. The aviation industry is based on technology. As a result, innovations will always be a key driver for this sector and its thriving supply chain, where technologies are continuously applied and researched to continuously increase performance [19].It affects both supply and demand sides by helping industries to maintain their competitive advantage [20], In the aviation industry, innovation is critical to improving efficiency and operational capabilities and creating value through improvements in air traffic control, advanced materials, more sustainable fuels, energy storage, digital transformation and mitigation of environmental concerns. All this provides new opportunities for the development of the aviation sector [21]. The aviation industry is one of the safest industries in the world. However, there is always an effort to increase the safety of this industry. One of the innovative solutions to increase the safety of the aviation industry is the use of artificial intelligence (AI) technology. Artificial intelligence technology can be used in various fields of the aviation industry and help increase its safety. One of the applications of artificial intelligence in the aviation industry is to use it to predict and prevent accidents. Artificial intelligence can predict the likelihood of accidents by analyzing various data, such as flight data, aircraft equipment data, and pilot performance data. This can help pilots and airline officials to take necessary measures to prevent accidents.Another

application of artificial intelligence in the aviation industry is to use it to automate some processes. Automating some processes can help reduce human errors and prevent accidents [22]. For example, AI can be used to automate flight control processes, aircraft maintenance processes and air traffic management processes.

In addition, artificial intelligence can be used to improve the training of pilots and airline workers. Artificial intelligence can help improve the skills of pilots and airline workers by providing training tailored to each individual's needs. This can help reduce human errors and increase flight safety.Some other innovative solutions to increase the safety of the aviation industry include:

- Using new materials and technologies to build airplanes
- Use of intelligent detection and warning systems
- Improving communication and cooperation systems between aircraft and ground stations
- Increase education and public awareness about flight safety.
- Optimizing flight routes to save fuel and reduce greenhouse gas emissions
- Allowing taxi and landing without human intervention.
- Detect fraudulent activity, such as ticket scalping or false claims

By using these innovative solutions, the safety of the aviation industry can be brought to a higher level and accidents can be prevented. The use of artificial intelligence in the aviation industry is still in its infancy, but it has the potential to revolutionize the way we fly. As AI technology continues to develop, we can expect more innovative applications that improve safety and efficiency and enhance the passenger experience [16].

3. findings

3.1. Applications of artificial intelligence in the field of airport runways

Airport runways, vital arteries in the circulatory system of global air travel, face a series of challenges that pose significant risks during aircraft taxiing and landing. Gang issues, especially crackdowns and disorderly conduct, are pressing concerns that require immediate attention. The current challenge lies in the inherent difficulties of timely diagnosis and management of these structural problems [18]. Recent years have seen an increase in runway-related incidents, with data showing a worrying link between runway conditions and aviation accidents. Runway cracks, often hidden below the surface, can compromise structural integrity and increase the risk of accidents during critical phases of flight—taxi and landing. The unpredictable nature of these issues exacerbates the challenge, as traditional inspection and maintenance methods may not be sufficient to detect hidden vulnerabilities [9].

In addition, the extensive nature of airport runways, often spanning several kilometers, poses a logistical challenge in terms of regular inspection and monitoring. Routine inspections, performed visually or using outdated technology, may miss subtle signs of degradation that AI-powered systems can pick up. The consequences of ignoring these challenges are severe, from wandering the runway on landing to damaging the undercarriage of the taxiing aircraft [27]. As airports around the world struggle to meet the ever-increasing demands of air travel, the importance of runway safety cannot be overstated. The current challenge is multifaceted: a combination of aging infrastructure, limited resources for manual inspections, and the vast scale of runway networks. To address this challenge, a paradigm shift is necessary, one that integrates advanced technologies such as artificial intelligence and drone systems to provide a comprehensive and proactive solution to the critical issue of runway integrity [28]. In the complex web of aviation safety, few components are as critical as the runway—the lifeline on which aircraft perform complex maneuvers during takeoff and landing. As global demand for air travel continues to increase, the need for robust runway infrastructure and proactive safety measures becomes increasingly important [29]. The current state of runway maintenance faces significant challenges, with deterioration and wear often not being addressed until it becomes a potential hazard. Airport runway

integrity incidents pose a serious risk to air travel safety and require a paradigm shift in monitoring and maintenance practices. The aviation industry is grappling with the need to adopt innovative solutions that not only enhance safety but also minimize air traffic disruptions [11].

Artificial intelligence, when integrated with drone technology, can revolutionize airport runway inspection by providing a proactive, data-driven approach. Traditional manual inspection methods are not only time-consuming but also prone to human error, making them inadequate for the rapid and comprehensive assessment required in today's dynamic aviation landscape [30]. Our exploration extends to the role of drones in this transformative equation. Equipped with advanced sensors and imaging technology, the drones act as eyes in the sky, performing real-time inspections and recording high-resolution data of runway surfaces. The synergy between artificial intelligence algorithms and data captured by drones provides an advanced solution for the early detection of cracks and runway irregularities, providing an unprecedented level of accuracy and efficiency in ensuring runway safety [4]. Airport runway slipperiness is one of the most important safety problems in the aviation industry. This problem can lead to serious accidents such as failed take-off, failed landing or deviation of the aircraft. One of the ways to reduce the slipperiness of the airport runway is to use appropriate materials and substructure methods. However, choosing the right substructure materials and methods can be challenging, as various factors such as the type of aircraft, weather conditions and rainfall in the airport area must be considered [7].

Artificial intelligence can help in this field. AI can predict runway slippage conditions by analyzing various data, such as weather data, flight data and runway performance data. This can help the airport authorities to choose the appropriate substructure materials and methods and take the necessary measures to reduce runway slipperiness [17]. Currently, various researches are being conducted in the field of using artificial intelligence to solve the slippery problem of the airport runway [21]. One of these researches was conducted by United Airlines. The company uses artificial intelligence to predict runway slippage conditions at various airports. This will help the company to take necessary measures to reduce runway slippage and increase the safety of flights [20]. In another study, researchers at Cornell University have used artificial intelligence to develop an automated system to detect tire slippage. Using various sensors, such as temperature and humidity sensors, this system detects the slippery condition of the runway in real time. This can help pilots avoid landing in slippery conditions [11].

With the advancement of artificial intelligence technology, it is expected that we will see more extensive applications of artificial intelligence in the field of airport runway infrastructure. This can help reduce airport runway slipperiness and increase flight safety.

Here are some specific applications of artificial intelligence in the field of airport runway infrastructure:

1. Runway slippage prediction: Artificial intelligence can predict runway slippage conditions by analyzing various data, such as weather data, flight data and runway performance data. This can help the airport authorities to choose the appropriate substructure materials and methods and take the necessary measures to reduce runway slipperiness.
2. Automating runway slippage detection: Artificial intelligence can detect runway slippage conditions in real time using various sensors, such as temperature and humidity sensors. This can help pilots avoid landing in slippery conditions.
3. Preventive runway maintenance: Artificial intelligence can predict the need for runway maintenance by analyzing runway performance data. This can help reduce maintenance costs and increase flight safety.
4. Identify potential hazards: AI can identify potential hazards using various data, such as radar data, weather data, and runway

performance data. This can help air traffic controllers to take necessary measures to prevent accidents.

5. Providing important information and warnings to pilots: Artificial intelligence can provide important information and warnings to pilots about runway conditions, air traffic conditions and other factors. This information can help pilots avoid accidents.
6. Automating some airport runway control tasks: Artificial intelligence can perform some airport runway control tasks automatically. This can help reduce the workload of air traffic controllers and improve safety.

By using artificial intelligence, the runway infrastructure can be designed and maintained in such a way that the slippery condition of the runway is minimized. This can help increase flight safety and reduce air accidents.

3.1. Application of artificial intelligence in the construction and control of landing gear

The landing gear of the plane is one of the vital components of the plane, which is responsible for the smooth and safe landing of the plane on the ground. The plane has two types of landing gear. The first type is under the wing or body, which is called Main Landing Gear [31]. To maintain balance, another landing gear called Nose Landing Gear is installed under the nose. Both of these landing gears are retracted into the body after take-off or takeoff to reduce air resistance and also to prevent stalling in the high intensity of the air flow at speeds above 800 km which are normal in flight. In some cases, the plane may reach the stage of opening the wheels in the checklist during the approach and landing stages, but the lights of opening the wheels and locking them do not turn on. which is called landing gear [19].

Figure 4. Landing with a technical fault of the landing gear

Usually, the pilot tries to close and open again once or twice, but these types of wheels are designed in such a way that if they don't open, repeating this is usually useless. This is where the pilot must execute the no-wheels landing procedure. In this part of the article, the mobile landing gear model is presented for easy landing without damage during landing gear. which is controlled and directed using artificial intelligence.

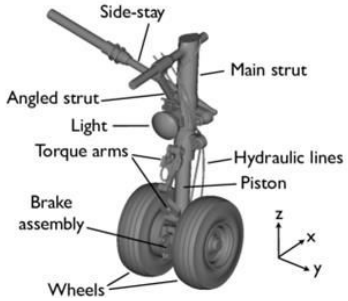

Figure 5. Commercial aircraft landing gear components [32]

The landing gear is one of the important parts of any type of aircraft, which is responsible for absorbing the energy caused by the landing of the aircraft. In the stages of designing an airplane, the design of the landing gear is usually done after the design of the body and wing of the airplane [14]. In fact, the design of the landing gear depends on the design of the body and the layout of the aircraft components and the location of the center of gravity of the aircraft [33]. Aircraft dynamics are often analyzed from two aspects. These two aspects are: 1- Investigating the stability conditions of the aircraft in different states 2- Calculation of the dynamic forces and accelerations on the aircraft [10].

Vibration absorber

Vibration absorber (Shock absorber) Vibration absorbers are systems that exist in different types and in different forms in landing gear. Some of the landing gear may not have tires, brakes, anti-skid systems, collection system or steering system, but there is definitely one type of vibration absorber in it. As can be seen from the name of the vibration absorber, the main purpose of its presence in the landing gear is to absorb the kinetic energy caused by landing or taxiing the aircraft. In general, there are two types of vibration absorbers: 1- The type in which a steel or rubber spring is used to absorb vibration. 2- The type in which fluid (gas or liquid) is used to absorb vibration, which is called the second type of pneumatic vibration absorbers. Usually, the gas used in it is dry air or nitrogen [4]. Nowadays, this type of vibration absorber is used in most airplanes. Oleo-pneumatic vibration absorbers have higher efficiency than other vibration absorbers and have better energy absorption [30].

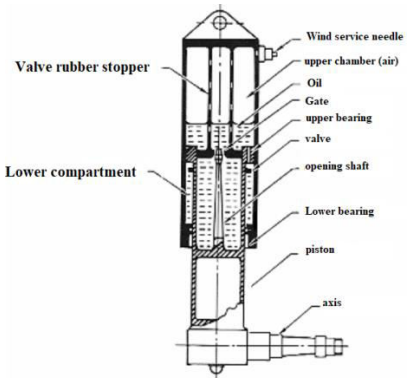

Figure 6. Oleo - Pneumatic vibration absorber[16].

By compressing a chamber of oil into a chamber containing dry air or nitrogen, the pneumatic vibration absorbers absorb the energy caused by the landing or taxiing of the aircraft. This energy, which is absorbed by the vibration absorber, forces the oil to pass through the valves built into the vibration absorber, and after creating pressure, dry air or nitrogen under pressure again presses the oil surface and forces it. to return to the primary oil chamber through the return orifices. Of course, the time of oil passage and return must be calculated [16].

Landing gear loading

In every aircraft, the system mechanism that must be used in the modes of sitting and taking off and guiding the aircraft on the ground is of particular importance, and the design principle of this system is called the landing gear and is based on the types of loads on them. Figure (7) shows the amount of force applied to the vibration absorber during the landing time [34].

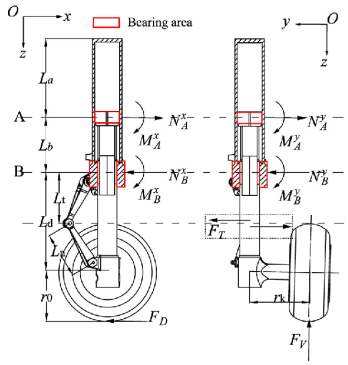

Figure 7. The amount of force applied to the vibration absorber

Check landing conditions

What is studied in this part is the analysis of the forces coming from the ground to the main landing gear and the nose of the aircraft in different landing positions. Because the airplane has different landing conditions, the forces acting on it should be analyzed in each landing situation. In each of the landing conditions, the external forces applied to the aircraft must be in balance with the linear and rotational inertial forces.

Two-point landing

A two-point landing is a landing where at the moment of landing, only two main wheels of the aircraft are in contact with the ground and bear the landing forces, and no force is applied to the nose wheel.

Equilibrium relationship along the Z direction

$$\sum F_Z = 0 \quad V_{MGr} + V_{MGL} = n_z W - L \,(1)$$

Equilibrium relationship in the Xdirection

$$\sum F_X = 0 \quad D_{MGr} + D_{MGL} = n_z W - L + T_{eng} (2)$$

L:Lift force

CG:Center of mass of the aircraft

W:Aircraft weight

T_{eng}:The driving force of the engine

D:Air resistance against horizontal movement

E:The distance of the center of mass of the plane from the ground

V_{MGr}:The vertical force on the right wheel of the main landing gear from the ground

V_{MGL}:The vertical force on the left wheel of the main landing gear from the ground

D_{MGr}:Longitudinal resistance force on the right wheel of the main landing gear

D_{MGL}:Longitudinal resisting force on the left wheel of the main landing gear

N_Z:Coefficient of inertial force in vertical direction

N_X:Coefficient of inertial force in the horizontal direction

By measuring the moment around the center of mass of the aircraft, the angular acceleration required for equilibrium conditions can also be obtained:

$$\sum M = I_y \theta$$

$$I_y \theta = B(V_{MGr} + V_{MGL}) + E(D_{MGr} + D_{MGL}) - ET_{eng} (3)$$

Three-point landing position

A three-point landing is a landing during which the main wheel and the nose wheel collide with the ground and participate in the analysis of forces coming from the ground. This type of landing creates critical conditions for the nose wheels. And in the two-point landing mode, critical conditions arise for the main wheels. The balance equations of the three-point landing position of the aircraft are calculated in the same way as for the two-point landing position:

$$\sum F_Z = 0 \quad V_{MGr} + V_{MGL} = n_z W - L \,(5)$$

$$\sum F_X = 0 \quad D_{MGr} + D_{MGL} = n_z W - L + T_{eng} (6)$$

For a three-point landing, it is assumed that the moment resulting from the rotation of the aircraft around y is prevented by the nose wheels. And as a result, the angular acceleration of the plane will be zero. Of course, this issue will increase the forces

on the nose wheels to the maximum possible extent.

$$\sum M_{CG} = 0 \;\; V_{NG}\, C - D_{NG} E = l(V_{MGr} + V_{MGL}) + E(D_{MGr} + D_{MGL}) - ET_{eng} \quad (7)$$

T_{eng}:The propulsive force of the engine in landing conditions (and it is usually assumed that this force is equal to the force of air resistance.

$T_{eng} = D$

Analysis of the landing gear

In calculating the forces on the aircraft, as explained, the forces on the landing gear have a higher importance compared to other parts. The landing gear is always exposed to the highest level of force and acceleration, both in different taxi conditions and in different landing situations. Therefore, most of the designers and manufacturers have limited themselves to the analysis of the landing gear instead of examining the whole aircraft and have achieved favorable results in this field as well [5-9]. The performance of the landing gear is studied from several aspects. In some sources [5], calculations of pressure, acceleration, force and displacement are discussed by using the form of vibration absorber of the landing gear and using fluid relationships.

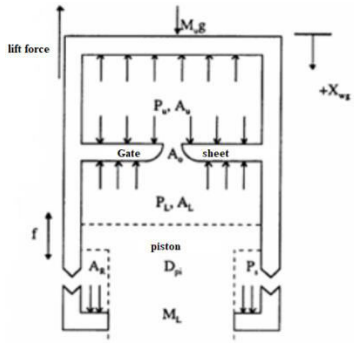

Figure 8. Schematic view of the internal mass and cylinder of the main landing gear[30]

Aircraft vibration simulation

Another way to analyze the landing gear is its vibration simulation. In this method, the chariot is simulated as a system with several degrees of freedom with a series and parallel combination of absorbers and springs, and its governing equations are extracted. Then it is subjected to stimulation conditions and the results are obtained using analytical and numerical methods. One of the common methods of simulation is in the form of one and two degrees of freedom, which is shown in figures (8 and 9) [32]. There are other methods that will be discussed in the next sections.

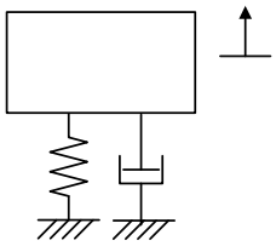

Figure 9. Simulation of one degree of freedom

One degree of freedom simulation

Landing gear can be simulated using geometric and physical characteristics in two ways, which is a mixture of mass, spring and damper.In the simulation of one degree of freedom, the whole landing gear together with the vibration absorber can be simulated as a system of one degree of freedom similar to figure (8) below. In this simulation, the shown mass represents the mass of

the airplane and k is the spring and C is the damper, respectively, replacing the stiffness (air) and damping (oil) of the landing gear vibration absorber. In this simulation, the mass and elastic properties of the landing gear tire have been ignored. The reason for this is regardless of the fact that the tire's mass and elasticity are insignificant compared to the landing gear and the mass of the airplane. Now the dynamic equations governing this system are extracted in this way. These equations can be solved using vibrational methods including Laplace for two specific and general solutions. F(t): can represent the input forces to the landing gear system.

$$mx + cx + kx = F(t)$$

To solve the above equation, displacement, velocity and acceleration are obtained as follows:

$$x(t) = 2V_0 me^{\frac{-ct}{2m}} \frac{\sin\left(\frac{Pt}{2m}\right)}{P}$$
$$P = \sqrt{-4km + c^2} (10)$$

$$v(t) = -V_0 ce^{\frac{-ct}{2m}} \frac{\sin\left(\frac{Pt}{2m}\right)}{P} + V_0 e^{\frac{-ct}{2m}} \cos\left(\frac{Pt}{2m}\right) (11)$$

$$a(t) = V_0 \frac{c^2}{m} e^{\frac{-ct}{2m}} \frac{\sin\left(\frac{Pt}{2m}\right)}{2P} - V_0 \frac{c}{m} e^{\frac{-CT}{2m}} \cos\left(\frac{Pt}{2m}\right) - \frac{PV_0}{2m} e^{\frac{-ct}{2m}} \sin\left(\frac{Pt}{2m}\right) (12)$$

The equations of acceleration, velocity and displacement are closely related to the initial conditions of the displacement and speed of the aircraft. For example, at the moment of landing and before contact with the ground, it is assumed that x(0)=0, x(0)=V, where V0 is the vertical speed of the aircraft and it is assumed that mg=L. Therefore, x(0)=0.

It is worth mentioning that in this solution it is assumed that k and c change linearly, but in reality they may change exponentially or polynomially. But it should be seen how much this assumption improves the solution of the equations. The differences in the dynamic response of the landing gear in different modes of landing and taxiing and when encountering obstacles are caused by the initial conditions of different external forces. Therefore, the solution of this equation or the governing equations will represent the solution of the basic equation of the dynamic simulation of the system.

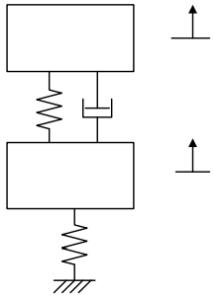

Figure 10. Simulation of two degree of freedom

Simulation of two degrees of freedom

In this case, the landing gear is simulated in the form of figure (10) where m_2, k_2 and c_2 represent the mass of the aircraft and the elasticity and damping properties of the vibration absorber. m_1 is a substitute for the mass of the landing gear, tire and its accessories and $k_1$is the elastic characteristic of the tire.The dynamic equations governing this system are derived as follows:

$.m_1\ddot{x}_1 + k_1x_1 - k_2(x_2 - x_1) - c(\dot{x}_2 - \dot{x}_1) = 0$

$.m_2\ddot{x}_2 + k_2(x_2 - x_1) + c(\dot{x}_2 - \dot{x}_1) = 0 (13)$

x_1: Moving the landing gear

x_2 :Moving the body of the plane

$\dot{x}_1$: Landing gear vertical speed

$\dot{x}_2$:Vertical speed of the aircraft body

Other applications of artificial intelligence in landing gear

Artificial intelligence can be used in various areas of aircraft landing gear and help improve its safety. One of the applications of artificial intelligence in aircraft landing gear is to use it to predict and prevent breakdowns. Artificial intelligence can predict the probability of failure by analyzing various data, such as flight data, aircraft equipment data and landing gear performance data. This can help pilots and airline officials take necessary actions to prevent crashes [30]. Another application of artificial intelligence in aircraft landing gear is to use it to automate some processes. Automating some processes can help reduce human errors and prevent breakdowns. For example, artificial intelligence can be used to automate landing gear maintenance processes [31]. In addition, artificial intelligence can be used to improve the training of pilots and airline staff. Artificial intelligence can help improve the skills of pilots and airline workers by providing training tailored to each individual's needs. This can help reduce human errors and increase flight safety [2].

Currently, many airlines and international organizations are researching and developing artificial intelligence applications in aircraft landing gear. It is expected that in the future, we will see more extensive applications of artificial intelligence in this field.Some specific applications of artificial intelligence in aircraft landing gear and damage control are:

1. Failure prediction: Artificial intelligence can predict the probability of failure by analyzing various data, such as flight data, aircraft equipment data, and landing gear performance data. This can help pilots and airline officials take necessary actions to prevent crashes.
2. Failure detection: artificial intelligence can detect landing gear failures using various sensors and cameras. This can help pilots and airline officials to take necessary actions to fix the failure.
3. Preventive maintenance: Artificial intelligence can predict the need for maintenance by analyzing the performance data of the landing gear. This can help reduce maintenance costs and increase flight safety.
4. Examples of artificial intelligence applications in aircraft landing gear:
5. "United Airlines" uses artificial intelligence to predict the failure of the landing gear of its planes. Using flight data, aircraft equipment data and landing gear performance data, the company predicts the probability of failure. This will help the company to take necessary measures to prevent failure.
6. "Emirates" airline company uses artificial intelligence to detect the failure of the landing gear of its planes. This company detects landing gear failures by using different sensors and cameras. This will help the company to take necessary steps to fix the failure.
7. The airline "Boeing" uses artificial intelligence for preventive maintenance of the landing gear of its planes. The company predicts the need for maintenance by analyzing landing gear performance data. This will help the company to reduce maintenance costs and increase flight safety.

Considering the advantages of using artificial intelligence in the aircraft landing gear, it is expected that we will see more extensive applications of artificial intelligence in this field in the future.

4. Conclusion

Artificial intelligence (AI) can play an important role in flight accident control, landing gear control and runway slippage. Artificial intelligence can be used to identify potential hazards, provide important information and warnings to pilots, and automate some air traffic control tasks. and help reduce the risk of air accidents.Identify potential hazards: AI can identify potential hazards using various data, such as radar data, weather data, and runway

performance data. This can help air traffic controllers take necessary actions to prevent accidents. Artificial intelligence can provide pilots with important information and warnings about runway conditions, air traffic conditions, and other factors. This information can help pilots avoid accidents and also automate some air traffic control tasks. This can help reduce the workload of air traffic controllers and improve safety.In addition to the mentioned, it can detect possible failures of the landing gear using various data, such as data from the landing gear sensors. This can help pilots take the necessary steps to land the plane safely. It can provide pilots with important warnings about the status of the landing gear. This can help pilots avoid accidents caused by landing gear failure. It can help identify runway slippage and provide important warnings to pilots. This can help reduce the risk of accidents caused by runway slippage.

The aerospace industry is rapidly adopting artificial intelligence (AI) to enhance various aspects of its operations, from designing and manufacturing aircraft to optimizing flight paths and providing personalized passenger experiences. AI is transforming the way aviation companies operate, making processes more efficient, safer, and customer-centric.AI is revolutionizing aircraft design by enabling engineers to analyze vast amounts of data and optimize aircraft performance, fuel efficiency, and safety features. AI is also being used to automate and optimize flight planning, crew scheduling, and aircraft dispatching, improving the efficiency and reliability of air travel.In addition to these operational improvements, AI is also enhancing the passenger experience. Airlines are using AI to personalize travel recommendations, provide real-time travel updates, and automate customer service interactions. AI is also being used to create immersive virtual experiences for passengers, making air travel more engaging and enjoyable.

As AI continues to mature, it is expected to play an even more significant role in the aerospace industry, leading to further advancements in aircraft technology, operational efficiency, and passenger satisfaction.AI automates repetitive and time-consuming tasks, reducing wait times and costs while freeing up employees to focus on more important responsibilities and address chronic staff shortages. Artificial intelligence is being implemented by airlines for facial recognition, customer Q&A, baggage checking, optimizing factory operations and optimizing aircraft fuel. AI has the ability to predict travel changes in traffic in advance and reasonably estimate the time required to reach any airport based on the time of day. Artificial intelligence also enables engineers to add new capabilities to passenger and military aircraft in emergencies. Artificial intelligence can also be used to increase security in the travel and tourism industry by identifying fraudulent activities and malicious behavior.

Travelers often struggle with navigating unfamiliar airports to find transportation and the rest of the post-flight experience. By collecting and analyzing various types of transportation and customer experience data, AI-enhanced apps can guide travelers to the baggage carousel and help them book a trip, and even refine it to points of interest. Point around. Suggest a time after getting off. The technology can continuously monitor weather conditions and other factors with the goal of reducing unplanned downtime. AI can also be used to identify hidden patterns to provide the airline industry with insights into other possibilities that could cause flight delays and cancellations. Some airlines have equipped the cabin crew with a data analysis program that provides detailed information about the passengers sitting in each seat. During and during the flight, this information can be used to make seat changes and adjust offers based on individual tastes.

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