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OPTIMIZATION AND SUSTAINABILITY OF CONVENTIONAL PROPULSION UNITS IN THE CONTEXT OF CURRENT ENVIRONMENTAL TRENDS

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Abstract

This article focuses on the current situation in the aviation industry in relation to environmental trends. In the introductory part, the situation on the aviation fuel market, their production and their current price is presented, while the emphasis is on familiarization with a more ecological form of traditional fossil fuels, namely sustainable aviation fuel. The reader is informed about the current situation in connection with emissions and greenhouse gases produced by air transport and the effort to reduce them and in the future their complete elimination. The second part presents the approach of aviation authorities such as EASA, FAA and ICAO, as well as their goals for reducing emissions and greenhouse gases and current projects for sustainable aviation. The article focuses on the implementation of sustainable aviation fuel in aviation and the issues associated with its use. The third part deals with the latest projects of aircraft and power units manufacturers. Other strategies such as CORSIA and ETS are presented, as well as climate conferences dealing with this issue. We point out the different approaches of countries in connection with the issue of reducing emissions. In the conclusion, we will evaluate the current situation with the economy and ecology in aviation from a global point of view, the actions of the authorities, manufacturers and point out the shortcomings.

Keywords

aviation fuel, sustainable aviation fuel, sustainable aviation, ecological strategies

1. INTRODUCTION

As in the whole world, in the world of aviation, ecology and sustainability is a hot topic. Aviation authorities are putting pressure on carriers to operate their flights in the most possible ecological way. In the terms of this direction, manufacturers of aviation equipment must also adapt, developing technologies that reduce the production of emissions of their aircraft and engines. Currently, aviation has focused on the development and implementation of sustainable aviation fuel (SAF). The use of sustainable aviation fuel is in initial phase and its price is high. The United States, as well as the European Union, are committed to further improving this technology, with the need to find new means, technologies, and also verify these technologies and build the entire infrastructure for the production of such fuel. The article also presents other options for reducing emissions, such as airspace optimization using free route airspace, functional airspace blocks (FABs) or improvements of SID and STAR procedures. The latest trends in aircraft and propulsion units manufacturing and their relationship to emissions reduction and sustainability are presented.

2. SUSTAINABLE AVIATION FUEL

The aviation industry contributes nowadays about 2% of the total carbon emissions of all industries, in the near future we expect continuous growth of air travel volume . Aviation has no sufficient short-term fuel alternative such as ethanol or electricity due to the energy density required, although it is possible to use jet fuel in fuel cells for local electricity generation in various applications.

Current aviation fuel production processes require huge facilities that are complex and expensive to operate, while the source of fuel production is oil. Reducing carbon emissions in the aviation industry is essential to combat global warming and increasing greenhouse gas concentrations. Use of alternative aviation fuel can achieve 50-95% reduction in carbon emissions and is therefore considered the most effective way to achieve carbon neutral aviation. For this reason, it is necessary and important to continue to address the used sources for the propulsion of aircraft engines to achieve a reduction in the emissions produced [1].

Biofuel, sustainable aviation fuel or SAF (Sustainable Aviation Fuel) is fuel that comes from renewable plant or animal sources. The energy of these fuels comes from biological carbon fixation, which is the conversion of carbon dioxide into organic compounds by living organisms. Examples of biofuels include:

- Bioethanol – alcohol produced by fermentation of carbohydrates found in crops such as corn. Non-food sources such as grasses are being developed for ethanol production
- Biodiesel – produced from vegetable oils and animal fats by a chemical process known as transesterification
- Methane - biogas produced by anaerobic digestion, decomposition of biodegradable material by microorganisms, from animal manure, waste from landfills or plant material [2].

Biofuels, if produced in a sustainable manner, can contribute more to climate change than fossil fuels mainly because, unlike fossil fuels, biofuels have the potential to remove carbon dioxide from the atmosphere during biomass growth as part of their production and use cycle. A key strategy of this initiative is the development and widespread use of biofuels of the required quality in air transport. Significant and sustained research and development of biofuels suitable for use in aviation is relatively new. Currently, however, it is necessary to find an alternative to fossil fuels if we want to achieve real carbon neutrality and reduce the environmental burden. The current primary focus is on a sustainable "drop-in" biofuel suitable for use in turbine engines. "Drop-in" fuel is a fuel that can be mixed with fossil fuel-based fuel and used without requiring any rebuilding of engines, airframes, or fuel distribution systems. To be considered sustainable, a biofuel should come from renewable sources that do not displace food crops or compete with food crops for land or water use. Ideally, they will also have a carbon-neutral life cycle (growth/production/use) and it is also desirable that the growth and production of biomass stocks has a positive local socio-economic impact. Some of the oleaginous plants that meet these criteria include:

- Camelina – an oilseed crop used as a rotation crop in modern agricultural practices
- Jatropha - A non-edible drought tolerant plant that can grow on marginal land
- Algae – simple, photosynthetic organisms that can be grown in wastewater or seawater

Aviation biofuels produced from these and other crops are referred to as synthetic paraffinic kerosene (SPK) or esterified free fatty acid (HEFA) fuel. In 2011, the international aviation and fuel communities approved the blending of petroleum fuels and biofuels for use in commercial aviation [2].

Current SAF Facts:

- More than 450,000 flights have taken off thanks to the SAF
- There are 7 production methods
- More than 300 million litres of SAF produced in 2022
- SAF can reduce emissions by up to 80% during the entire life cycle.
- In 2022, the purchase of the SAF for approximately 17 billion US dollars is agreed
- So far, more than 50 airlines have experience with SAF [3].

Despite being touted as a solution to reducing carbon emissions, SAF is generally much more expensive than standard Jet A-1 aviation fuel. Airlines are therefore worried about how they will be able to use SAF, as they are expected to fulfil their emission obligations to the authorities, while the main reason for the slow integration is the price. IATA noted that with the right policy support, SAF could account for 2% of all aviation fuel by 2025. The year 2025 is therefore set to become a turning point in SAF's competitiveness in the field of fossil fuels.

Currently, SAF is neither plentiful nor cheap. In Europe, the typical price of fossil-based kerosene is €600/t, compared to SAF made from cooking oil, which can range from €950/t to €1015/t. Prices vary, but the total unsubsidized cost can be four times higher per gallon than regular jet fuel. The carbon savings from SAF, while significant, are also relatively expensive, measured in dollars per ton of reduced CO2 production. Politicians around the world are taking drastic steps to cut costs and increase supplies. In the US, tax credits and other financial incentives play a huge role in reducing the cost of SAF, while in the EU the proposed mandatory SAF shares are expected to be supported by an increase in their production. By 2040, we do not expect a significant reduction in SAF costs, as the availability of raw materials for certain types of SAF is limited, and the production and overall competitiveness of sustainable fuel types must also be significantly increased [4][5][6].

3. APPROACH OF AVIATION AUTHORITIES

Aviation authorities like the European Union Aviation Safety Agency (EASA), the Federal Aviation Administration (FAA), and the International Civil Aviation Organization (ICAO) have been actively involved in promoting sustainable aviation in recent years. The aviation industry is a major contributor to greenhouse gas emissions, and as concerns about climate change have grown, these authorities have recognized the need to take action to reduce the industry's impact on the environment. One of the key approaches of these aviation authorities has been to set environmental standards and regulations for the aviation industry. For example, the ICAO has established a set of environmental goals for the industry, which include improving fuel efficiency, reducing carbon dioxide emissions, and minimizing noise pollution. The ICAO has also developed a global market-based measure for carbon offsetting and reduction, known as CORSIA, which aims to offset the growth of international aviation CO2 emissions from 2020 levels.

The EASA, on the other hand, has been working on updating regulations to ensure that new aircraft designs and technology are more environmentally friendly. In addition, the EASA has developed guidelines for the certification of sustainable aviation fuels, which can be made from various feedstocks such as waste oils, non-food crops or municipal solid waste, among others. These guidelines provide a framework for the use of sustainable fuels that can reduce carbon emissions by up to 95%.

The FAA has also been taking steps to promote sustainable aviation. The FAA's Continuous Lower Energy, Emissions and Noise (CLEEN) program provides funding for research and development of new technologies that reduce emissions and noise. Additionally, the FAA has established a program to incentivize airlines to use more fuel-efficient aircraft, and has worked with the aviation industry to develop a voluntary program called the Aircraft Certification Environmental Program, which encourages the use of more environmentally friendly technologies and practices in aircraft design and operation.

Another approach taken by these aviation authorities is to promote the adoption of sustainable practices in the industry. For example, the ICAO has been working to promote the use of sustainable aviation fuels and has established a task force to develop guidance for the deployment of such fuels. The FAA has also been promoting the use of sustainable aviation fuels, and has worked with airlines to develop sustainable aviation fuel supply chains [7][8][9][10][11][12][13][14][15][16][17][18].

4. OPTIMIZATION OF THE AIRSPACE

4.1. Functional Airspace block

European airspace is divided into seven functional airspace blocks (FABs). A functional airspace block is an airspace management concept in Europe that involves the coordination and integration of air traffic services in a defined airspace block. The FAB aims to improve the efficiency and safety of air traffic management in Europe by reducing fragmentation and increasing cooperation between the various Air Navigation Service Providers (ANSPs) and their respective national authorities. FABs are established based on geographic proximity and operational requirements and usually consist of several neighbouring countries. Each FAB is governed by a specific set of regulations and agreements and is responsible for managing the airspace within its boundaries. The FAB concept was first introduced in 2004 as part of the Single European Sky initiative, which aims to harmonize and integrate air traffic management across Europe. FAB implementation has been gradual and as of 2021 there are nine FABs established in Europe covering most of European airspace [19][20].

Among the advantages brought by the implementation of FAB in the European airspace, we can include:

- Improved safety: By coordinating and integrating flight services in a defined block of airspace, FABs can improve safety by reducing the risk of crashes and other safety incidents.
- Increased efficiency: FABs increase efficiency by reducing airspace fragmentation and improving the coordination of air traffic services. This can lead to shorter flight times, minimization of delays and lower fuel consumption, resulting in cost savings for airlines and reduced environmental impact.
- Increased capacity: FAB increases capacity by optimizing the use of airspace and resources such as air traffic controllers and communication systems.
- Harmonization of regulations and procedures: FAB can harmonize regulations and procedures in multiple countries, making it easier for airlines to operate cross-border flights and reducing the administrative burden on air navigation service providers (ANSPs).
- Increased collaboration: FAB encourages increased collaboration between ANSPs and their respective national authorities, which can lead to greater sharing of expertise and best practices [19][20].

4.2. Free Route Airspace

Free Route Airspace (FRA) is a relatively new concept in air traffic control that allows aircraft to fly between designated entry and exit points in defined airspace without being restricted to predefined Air Traffic Control (ATC) routes. In FRA areas, aircraft operators can plan their preferred routes and flight paths based on their operational needs, and air traffic controllers ensure that all aircraft remain safely separated from each other.

FRA is typically implemented in upper airspace where there is less air traffic and more room for flexible routing. Increasingly, FRA is also being applied to areas of lower flight levels thanks to new and more accurate technologies and procedures. FRA is based on a new generation of air traffic management systems capable of tracking aircraft in real time and providing more accurate and timely information to air traffic controllers. These systems include Automatic Dependent Surveillance–Broadcast (ADS-B), which allows aircraft to transmit their position, altitude and other data to ground receivers, and the Airport collaborative decision-making (A-CDM) system, which allows all parties involved in flight operations to share information and make joint decisions. To ensure safe and efficient operations, air traffic controllers use advanced computer systems to monitor and control aircraft in real time and to ensure that all flights follow prescribed distances and are not compromised. Coordination with the neighbouring airspace sector and other stakeholders in the air traffic management system is also needed. Full implementation of the FRA is expected by 2025 [21][22][23].

By fully integrating this strategy into flight operations, it is possible to save:

- billion nautical miles
- 6 million tons of fuel
- 20 million tons of CO2
- Fuel worth 5 billion euros [21].

The proportion of flight time flown in FRA airspace was 68% in 2021, compared to 8.5% in 2014. We estimate that FRA implementation has saved 10 million tonnes of CO2 since 2017. This corresponds to approximately 170,000 return flights between Madrid and Riga. In order to advance cross-border implementation of FRA, NM (Network manager) should increase its efforts in the implementation of cross-border projects by air navigation service providers. In addition, the implementation of new airspace design projects by 2030 is expected to further reduce CO2 by 2.5-3.5% per flight with the current trend of increasing flight efficiency [24]. However, the goals of the ”Fit for 55” plan are to achieve a 55% reduction in the production of clean greenhouse gases, which means that the introduction of the FRA and its development will only contribute very little to meeting these regulations and goals.

4.3. SID&STAR

SID and STAR are two commonly used terms in aviation related to aircraft navigation. SID stands for Standard Instrument Departure. This is a published procedure for navigating an aircraft from the airport runway to the en-route flight phase using designated navigation points. The purpose of the SID is to ensure the safe and efficient flow of traffic by providing a predetermined route for departing aircraft. SIDs include altitude and course limitations, as well as information on required radio frequencies and communication procedures.

STAR stands for Standard Arrival Route. It is also a published procedure that navigates pilots using predetermined waypoints from the flight phase to the landing phase. The purpose of STAR is to ensure the safe and efficient flow of traffic by providing a predetermined route for arriving aircraft. STARs contain altitude and speed restrictions as well as information on required radio frequencies and communication procedures [25][26].

One of the disadvantages of SID and STAR is that they can increase the complexity and workload of pilots and air traffic controllers. These procedures require both parties to be highly skilled and experienced, which can be challenging for less experienced pilots and controllers. This can lead to delays and problems, especially during periods of high traffic. Another disadvantage of SIDs and STARs is that they can be restrictive and inflexible. For operational reasons, pilots may prefer to use their own routes or deviate from the prescribed route, but this is not always possible. This can lead to inefficiencies and delays as pilots may be forced to steer the aircraft along a fixed route. In terms of environmental sustainability, SID and STAR can have a negative impact on noise and air quality, especially in areas near airports. Aircraft following these procedures may produce more noise and emissions, which may affect local communities and the environment.

When simulating a flight from Amsterdam Airport to Frankfurt Airport, the effect of different parts of the route on the flight time was fully tested using three types of flights. The first case was a typical flight plan that would currently be executed using SID and STAR and navigation using waypoints. Two more test flights were conducted to see what effect each particular variable had on flight duration and efficiency. The second test flight used only SID and STAR, but did not use waypoints after the final waypoint on SID was reached or until the first waypoint on STAR was reached. The last test flight was done without using any SIDs or STARs or waypoints and was essentially flown straight through. The results show that simplifying the flight plan by removing waypoints and/or SIDs and STARs significantly reduces flight time and fuel consumption. From the results, it can be seen that on this particular route, the removal of waypoints does not bring any significant benefits, as only 1 minute of flight time is saved. The fuel saving is slightly more, 2.4%, compared to a flight using waypoints. The same can be said about the distance saved, which decreased by only 7.4%. When SID and STAR are removed from the flight plan, the benefits are much greater. When it comes to time saved, there is a big advantage over flying a typical route, saving a total of 12 minutes (22%). Fuel savings of 21.5% are also significant.

From the above results, it can be concluded that there are advantages for short flights using SID and STAR and without waypoints compared to the current way of conducting the flight. Significant reductions in fuel consumption and time can be achieved if flights are operated on direct routes regardless of any restrictions [22].It should be noted, however, that efforts are constantly being made to optimize the use of SID and STAR, including the use of RNAV (Area Navigation) procedures, Continuous Descent Operations (CDO), flexible procedures and dynamic airspace configurations.

5. THE LATEST PROJECTS OF ENGINE AND AIRCRAFT MANUFACTURERS

5.1. Airbus

The Airbus A321XLR is a long-haul narrow-body aircraft project. Airbus A321XLR has a longer range, which is up to 15% greater than the previous version of the A321LR. It can fly a distance of up to 8,700 km and has a capacity of up to 220 passengers. Intergenerational progress amounts to 30% less consumption per passenger. The main reason for the development was the need to provide transport capacity and a range that would allow the operation of the aircraft in an even greater horizon. In addition, the cargo space and the usability of the cabin for passengers have also been improved. Other improvements include a new and more powerful engine that delivers lower fuel consumption and thus lower running costs. Aerodynamic improvements contribute to reducing drag and increasing flight efficiency. Thanks to new avionics technologies and instruments in the cockpit, the controllability of the aircraft and the safety of operation are improved. The Airbus A321XLR has won the favour of many airlines due to its improvements and advantages. Hundreds of these aircraft have already been ordered as proof. Thus, the A321XLR is one of the most successful aircraft projects today and is expected to be an important player in the market for years to come [27][28][29].

Airbus ZeroE is a project that aims to create the world's first zero-emission commercial aircraft. The goal of the project is to lead the entire aviation industry to decarbonization and reduce the negative impact of aviation on the environment. The main energy source for the Airbus ZeroE propulsion is hydrogen, the combustion of which produces no emissions. Three conceptual models were revealed as part of the project. The first concept is a jet engine with a range of more than 2,000 nautical miles, capable of operating across the continent and powered by a modified hydrogen turbine engine. Liquid hydrogen will be stored and distributed using tanks located behind the rear pressure dam. The second concept is a turboprop design that is also powered by hydrogen. This concept would be able to fly more than 1,000 nautical miles, making it a good choice for short flights. A third concept is a blended wing aircraft in which the wings are joined to the main body of the aircraft with a range similar to the turbine design concept. The exceptionally wide hull section opens up multiple options for hydrogen storage and distribution and for cabin layout. The ZeroE project is still in the conceptual stage and Airbus plans to continue to develop and refine the designs in the coming years. The company aims to have the ZeroE aircraft in commercial operation by the mid-thirties. Airbus has pledged to be able to produce aircraft with zero carbon dioxide emissions by 2035 [30][31].

The Airbus Maveric project aims to develop a new type of aircraft with an asymmetrical design of the fuselage and V-shaped wings, which should be able to reduce fuel consumption and carbon dioxide emissions. This aircraft should be suitable for short routes and should be able to significantly reduce the noise produced. The first prototypes of the aircraft are currently being tested, and it is expected that it could enter service within the next few years. According to estimates, the Airbus Maveric aircraft should be able to reduce fuel consumption and carbon dioxide emissions by 20%, with a positive impact on the environment and climate change. The Airbus Maveric project is an important step for the company in its efforts to improve the environmental sustainability of aviation [32].

Airbus is also dealing with the issue of SAF, considering its use as a key strategy to reduce the environmental impact of its aircraft and operations. Airbus has set a goal for all its aircraft engines to be certified for the use of 100% SAF by 2030. This goal is part of the company's broader efforts to reduce its carbon footprint and contribute to the decarbonization of aviation. Airbus is also involved in several projects

5.2. Boeing

Among his current most promising projects we can include:

- Production of the 777X aircraft
- Recycling of materials
- Development of recyclable materials
- EcoDemonstrator project

The Boeing 777X represents the latest generation of commercial aircraft produced by the company. The Boeing 777X uses the latest technologies, including advanced on-board systems that allow the aircraft to achieve high flight efficiency and safety, improved flight control and navigation. Thanks to these technologies, it can significantly optimize fuel consumption and thereby reduce emissions. One of the most significant advantages of this project is its high capacity. The Boeing 777X can carry up to 425 passengers, which is 20% more than its predecessor, the Boeing 777-300ER. Another advantage of the Boeing 777X project is its fuel efficiency. The aircraft uses state-of-the-art GE9X engines, which are 10% more efficient than the engines of its predecessor, the Boeing 777-300ER. According to data from Boeing, the Boeing 777X is up to 12% more fuel efficient than its closest competitor, the Airbus A350-1000. Boeing has also significantly worked on the lower noise level of the aircraft due to increasingly strict standards around airports [33][34].

Boeing has long-standing commitments to recycling and developing new eco-friendly materials, environmental protection and sustainable development. The company is committed to reducing greenhouse gas emissions, minimizing waste and using renewable energy sources. As part of these commitments, the company has developed various recycling projects. An example can be cooperation with the company ELG Carbon Fiber for the recycling of carbon fibers from aircraft production [35][36].

The Boeing EcoDemonstrator is a project that aims to improve the environmental sustainability of aviation by testing new technologies and innovations. One of the main areas of focus of the EcoDemonstrator project is fuel technologies. Boeing is testing different types of biofuels made from different sources, such as vegetable oils, waste oils and even residues from alcohol production. In addition, Boeing is also testing new technologies that enable better monitoring of aircraft emissions The Boeing EcoDemonstrator tests new materials and structural elements that can help reduce the weight of aircraft and thus further increase their efficiency. Boeing EcoDemonstrator also tests new technologies in flight operations. Boeing has been testing new technologies that allow pilots to use alternative flight paths that minimize the amount of fuel that is consumed during flight [37][38][39].

5.3. Embraer

The company's latest project is the E2 project. The E2 is a project of Embraer's newest aircraft series. These planes are intended for 80 and 132 passengers respectively in the largest version, so we can consider it as a smaller transport plane. Embraer was able to achieve up to 25.4% higher fuel efficiency per passenger than the first E series, while it has 10% lower fuel consumption compared to competing aircraft. In this way, they were able to adapt to the current trend of using smaller but more efficient and profitable aircraft. The E2 series also reduced noise by up to 65% compared to the E series, thanks to the use of noise-absorbing materials, air conditioning dampers and improved chassis aerodynamics. The use of new power units also contributed to the reduction of noise, which allows aircraft to optimize the flight path and thus increase fuel efficiency. Thanks to this, it can reduce the production of emissions by 30%, 37000kg per flight, which represents 1 million tons of CO2 of a fleet of 10 aircraft of this type in 10 years [40][41][42].

The Energia project is the latest project of the Embraer company, where it also cooperates with Air New Zealand and Ruili Airlines. Embraer presented four concepts of the Energia program as its vision for sustainable aviation with zero emissions until 2050. The concepts included the Energia Hybrid project in the form of a nine-seater aircraft with electric motors with a range of at least 926 km and a single-piston engine, and the Energia Electric project, in which they presented a fully electric nine-seater aircraft. The third concept was the Energia H2 Hydrogen Fuel Cell, a 19- to 30-seat aircraft using fuel cells to convert hydrogen into electricity. The fourth was the gas turbine-powered version of the Energia H2, a 35- to 50-seat aircraft with two gas turbines that would use hydrogen for short flights and sustainable aviation fuel (SAF) for longer flights. Emissions reduction of up to 90% is estimated for these aircraft [43].

6. CONCLUSION

The aviation industry makes great efforts to comply with the requirements of aviation and governmental authorities (e.g. EU)authorities. The introduction of sustainable aviation fuel into air transport is a complex issue, financially extremely costly and lengthy process, and therefore we currently perceive its benefits as minimal. It will take a long time to develop and build the entire infrastructure for its production. By optimizing the airspace, better results would be achieved in a shorter period of time, but especially the reduction of emissions created by air transport to achieve significant goal in climate change protection. If we focus at air transport from a global perspective, it creates less emissions and greenhouse gases than other means of transport, such as road and shipping. Also, the inaction of some states in activities aimed at the sustainability of air transport, but also in industry, such as China, degrades the efforts of participating states to create a sustainable aviation, in which billions of dollars are invested to develop new technology and innovation.

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