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Research on the Improvement of Aircraft Fuel Efficiency by Improving Engine Structures

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Abstract: This essay focuses on what should be done to improve the efficiency of aircraft engines and the importance of this issue, such as saving resources and protecting the environment. It also mentions the existing engines they are usually used in which aircraft and what their maximum efficiency is. This article also mentioned what factors affect the fuel consumption of an aircraft engine in its operation, some online information is read about them, and in which cases the engine's efficiency is reduced. Recommendations or solutions are given for this, for example, by improving technology and inventing new energy sources to reduce consumption or by avoiding situations where designers can choose to do so. At the end of the article, a conclusion is given to summarise the significance of this article in terms of saving the use of fuel in aircraft. This will not only greatly save non-renewable resources but also protect the environment by reducing the production of more carbon dioxide to prevent the intensification of the greenhouse effect. In addition to the fact that many airlines spend an enormous amount of money on fuel each year, this would also save them a great deal of money to do other things to improve the quality of their services and promote the development of their airlines.

Keywords: aircraft fuel efficiency, engine structures, improvement

1. Introduction

In recent years, with the development of technology, aircraft are equipped with more and more types of engines, such as the traditional turbine engine. This engine was the main type used in early jet aircraft, drawing air in and ejecting it through the combustion of hot gases produced to generate thrust. However, due to their higher fuel consumption and lower efficiency, modern commercial airliners rarely use this engine. In addition to this, another type of engine is the turboprop engine. This type of engine combines the characteristics of a jet engine and a traditional propeller engine. They have a jet engine at the aircraft's rear but transmit power to the propeller at the front through a shaft. Turboprop engines are usually used in regional and short-haul aircraft, such as regional airliners and transport planes. In addition to the two mentioned above, the turbofan engine is the most common engine used in modern commercial aircraft. The turbofan engine bypasses part of the airflow around the combustion chamber, making the outside of the engine appear to have a large fan cowl. This design provides both high thrust and improved fuel efficiency, allowing modern airliners to fly long distances over a wider area. Of course, turbine engines are also a thing, and this type of engine is usually used in helicopters and some vertical take-off and landing aircraft. They transfer power to a rotating wing or rotor via a shaft rather than producing direct jet thrust. The last typical type of engine is This type of engine is usually used for space flight or hypersonic flight. They produce a high-speed exhaust stream by burning fuel, which generates great thrust.

Although the above engines have been successfully used in engines, their efficiency has not yet reached a high level, only 40 to 60 percent. It needs some methods to improve, such as the use of lightweight structural materials, such as composite materials and advanced alloys, which can reduce the overall weight of the aircraft, thereby reducing fuel consumption, or through the improvement of the aerodynamic design of the wings, fuselage, and other aircraft Or by improving the aerodynamic design of the wings, fuselage, and other aircraft components, the wind resistance of the aircraft can be reduced, thus improving the flight efficiency. Of course, the aeronautical engineering sector has been continuously exploring new technologies, such as hybrid power systems, electric aircraft, and renewable energy, which can improve fuel efficiency to a certain extent. Of course, the most effective is still directly from the engine structure, through optimizing the design and replacing materials to improve fuel utilization efficiency. For example, Tetsuya Sato et al.-proposed an ATREX engine, The British Reaction Engine Company's SABRE and Scimitar engines, Yao et al.'s NUAA-PTRE engine, and the British Reaction Engine Company's SABRE engine. The unifying element of the designs mentioned above is the application of inlet air pre-cooling technology with a mix of turbine, rocket, and ramjet engines [1]. The development and technological advancement of ultra-high aspect ratio wing configurations is a key enabling strategy for the required step change in aircraft performance needed to increase air traffic volume while improving its sustainability for the next generation of air transportation.

The ultra-high aspect ratio wing construction, however, carries heavier weights when compared to normal aircraft, which presents difficulties for the design of aircraft configurations and related technologies [2]. Additionally, to solve the low efficiency of turbine engines at high Mach numbers, resulting in insufficient thrust, the effective operating range of the pre-cooler is enlarged using the dual-fuel approach of ammonia and n-decane. On the one hand, by adjusting the internal structure to work at low speeds, it is possible to counteract some of the negative effects and thus save energy and improve the fuel efficiency of the aircraft. On the other hand, when running in turbojet engine mode at high speeds, equivalent fuel pre-cooling in conjunction with low-pressure turbine guide vane adjustment helps to increase efficiency and thrust [3]. Airplanes are fuelled by fuel, and improving efficiency can save money. In addition to this, as fuel is a non-renewable energy source, it takes a lot of time to store it once it is used in large quantities. As international trade becomes more prevalent and the number of airplane flights continues to increase, new technologies are needed to reduce fuel use so that it is not over-consumed. Improving fuel efficiency also saves resources, as well as polluting the environment. Of course, it also reduces noise.

2. Case Description: Types of Engines on Common Aircraft

First, the turbofan engine is a sophisticated and complex mechanism.

Complex transient operations like start-up, shutdown, and loaded operation are inevitable for the engine. Compressors may experience an unstable and dangerous stall or surge during start-up. It is efficient to conduct experimental research using a genuine engine system to assess the turbofan engine's transient performance. However, given its high price and considerable danger, it is not viable. So, using a simulation model to analyze the behavior of a turbofan engine is an alternate and efficient technique to lower costs and risk [4].

Second, early turboprop engines have issues, including high noise and poor flight speed, compared to turbojet and turbofan engines.

It's encouraging that modern turboprop aircraft can fly at high altitudes and subsonic speeds, thanks to environmental awareness and a commitment to finding solutions. For instance, the A400M

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aircraft's TP400-D6 engine, the most potent three-spool turboprop engine in Western aviation, has a cruise speed of 781 km/h at 9450 m, or an approximate Mach number of 0.72, demonstrating that modern turboprop aircraft performance can be on par with that of turbofan aircraft. Because of their high power-to-weight ratio, high take-off thrust, and low specific fuel consumption, turboprop engines are frequently used in military transport regional and early warning aircraft [4].

Third, the main power source for aircraft is its jet engine.

Numerous advancements in turbojet engines have been made since the 1930s. A type of air-inlet base jet engine known as a turbojet technology consists primarily of a nozzle and gas turbine combination, typically with a turbine-driven compressor and combustion chamber. Although turbojet engines' construction materials and thermal characteristics have advanced, this technology has not yet reached its full potential. Although turbojets are key components of aviation systems, several other aircraft engine types, including turboshaft, turbofan, and turboprop, were created from turbojets for various applications. The current key challenges with turbojet engines are their inefficiency, permanent issues, search for alternate fuels, and environmental concerns [5].

Thermodynamic analysis typically uses the first and second laws of thermodynamics to establish the characteristics of turbojet engines. The energy dispersion of turbojet engines, including energy losses, energy efficiency, fuel energy, and product energy, may be seen using the first law of thermodynamics. However, improving the system and determining the turbojet engine's irreversibility is not at the necessary level. So, of the methods that can be used, applied inside the two laws. The real situation of the turbine engine in special conditions and the disadvantages that are difficult to change are studied using the analysis. The feasibility of this method can be almost zero because it's hard to obtain [6].

3. Analysis of the Problem: Factors Affecting Fuel Efficiency of Aircraft Engines

3.1. Flight Speed and Altitude

The fuel efficiency of an aircraft will vary at different speeds and altitudes. Higher altitude flights are typically more fuel efficient because the aircraft can fly in thinner air, reducing air resistance. Choosing an appropriate flight altitude can help to minimize fuel consumption. In general, the higher the aircraft's altitude, the less air resistance there is, and the less fuel is required. However, wind speed and weather may affect an aircraft flying at too high an altitude level. Besides, fuel consumption can generally be reduced by lowering the flight speed within the appropriate range. When the flight speed is too fast, the air resistance increases, and the fuel required will also increase. Therefore, to ensure flight safety, reasonable flight speed control can balance the relationship between flight speed and fuel efficiency [7].

3.2. Weight

The weight of an aircraft affects its fuel efficiency. Lighter aircraft usually require less fuel to keep them flying. Fuel efficiency is approximately higher when the aircraft is at a higher altitude [7].

3.3. Distance Flown

The distance flown affects fuel consumption. Longer flights may require more fuel to carry, thus increasing the aircraft's weight. More fuel is needed when the aircraft is far away [7].

3.4. Flight Pattern

The take-off and climb phases usually require more fuel because the aircraft needs to overcome gravity and air resistance. The cruise phase is more fuel efficient, while the descent and landing phases may require some fuel for control and deceleration [7].

3.5. Aircraft Type and Design

Different aircraft types have different design features, including wing shape, engine type, etc., which affect fuel efficiency. The aerodynamic principles of an aircraft wing, as the main lift and stability-generating component of a vehicle, are critical to flight performance. The wing's design and performance optimization directly affect the aircraft's handling, fuel efficiency, and flight safety.

An aircraft wing usually consists of a wing root, a wing tip, a wing span, and a wing area. The shape, extension, and aerodynamic profile of the wing have a significant impact on flight performance. Different wing designs suit different flight missions, such as low-speed take-off and landing, high-speed cruise, etc. [7].

Lift is the force that supports the weight of an aircraft, and its formation mechanism is based on Bernoulli's law. When airflow passes through a wing's upper and lower surfaces, upward lift is generated due to faster airflow and lower air pressure on the upper surface and slower airflow and higher air pressure on the lower surface [7].

3.6. Climatic Conditions

Meteorological conditions such as temperature, humidity, and wind speed can affect the fuel efficiency of an aircraft. Higher temperatures or humidity may affect engine performance, reducing fuel efficiency.

All in all, these factors are very important for the fuel efficiency of the aircraft. Suppose designers want to improve the efficiency of this. In that case, people should focus on each point, and understand each factor needs to improve the point to improve efficiency. The higher the temperature, the lower the air density. In the case of the engine speed remains unchanged, the amount of air entering the aircraft engine per unit of time is reduced, the boost ratio is correspondingly smaller, and the engine thrust will be reduced. In addition to this, air temperature affects the configuration of the aircraft load and fuel capacity. Of course, there is also the effect of air temperature. Air temperature also greatly impacts the take-off and landing of the aircraft. If the temperature of the airport is too high, the take-off thrust of the aircraft will be attenuated greatly, and the same weight may not be able to take off because the temperature is too high, and it can only wait for the sun to set or cool down before it can take off. The higher the temperature is, the thinner the air is, and the relative vacuum speed needed for the same large lift is also larger, so the ensuing super-wheel speed limitation, super-flap maneuvering limitation, and so on are all very great influences on the safety of flight. The higher the temperature, the thinner the air, the greater the relative vacuum speed [7].

4. Suggestions

4.1. Comparison

In previous spark ignition engines, paraffin usually had a detonation value which was mainly due to high cetane number. According to research, one needs to combine physical and chemical properties to try to solve this problem. According to professionals, a substance called pentanol can significantly slow this down. In addition to this, it has been found that some of the features of paraffin can also be improved by adding a certain amount of lighter components.Engine control experiments are used as examples, and the simulation findings are contrasted with some earlier studies and traditional control. In all kinds of results show that the use of science and technology for computational prediction and management allows better control of aircraft fuel ratios. Or rather, some hypotheses have been proposed during the years. Using the mean value model, such as scientists adjust the degree of throttle consumption based on various calculations and studies. However, the compensatory model ignores some issues, which leads to the need to reconsider some factors must be considered in fuel injection models [8]

4.2. Solutions

Aircraft need to emit a certain amount of carbon dioxide during long-haul flights, and how to reduce this emission is now a difficult challenge. Currently available technologies are not sufficient to replace them completely, but can only be replaced by less efficient sources of energy or materials. In a previous study, In recent years, the authors have reflected on the technologies available to us today and the results, including a variety of materials and energy sources or alternatives including methanol, ethanol, 100 per cent SPK, liquid hydrogen (LH2), liquefied natural gas (LNG) and liquid ammonia (LNH3). In order to test the ability to reduce the environmental impact of undesirable airborne gases [9].

Kerosene is easier to knock in spark ignition engines due to its low octane number (high cetane number). This problem has been attempted to be solved by altering the physical and chemical properties of the fuel. According to Chen et al., pentanol can significantly reduce RP-3's cetane number. Kerosene's atomization and evaporation performance may be improved by adding a specified quantity of light components. According to Song et al.'s research, adding ethanol at a 20% volume fraction might significantly enhance kerosene's atomization properties. The viability of combining alcohol and kerosene for spark ignition engines was examined by Liu et al. The combined benefits of butanol (renewable, high flash point, and high research octane number) and kerosene (high flash point and high energy density) should make n-butanol/kerosene mixed fuel suitable for spark ignition aviation piston engines. As a result, the n-butanol/kerosene binary fuel's combustion and emission characteristics were evaluated using an aircraft piston engine with spark ignition [10].

In previous research, the main focus has been on a variety of new technologies as well as various models and studies on energy and money. Although after so many years of research there is already a certain foundation and know the general direction. However, if we want to further enhance the pre-cooling degree of high fuel oil, we need to consider other more important factors. Perhaps we can make a more daring attempt in these completed ideasAs a result, this approach falls short of maximizing fuel pre-cooling's potential to enhance engine performance. On the other hand, a major problem in the thermal cycle analysis of pre-cooled engines is the efficient matching of aircraft and pre-cooled engines. The Concorde and Boeing 777 aircraft were used as test platforms in research evaluating the impact of fuel-pre-cooled engines on the aircraft's flight mission and design characteristics, respectively. The conditions in their study were ideal because they gave the ratio a value of 1. However, during the design process, the conditions that need to be considered are not so much as complete combustion also need to be based on the exit temperature in order to more accurately arrive at a result. In addition, aircraft often have air to fuel ratios that are much higher than average or much higher than the optimum ratio (air rich) required for fuel combustion in the chamber or its localised areas. Therefore we still need to improve the deficiencies [1].

5. Conclusion

5.1. Key Findings

This article describes ways to improve the fuel efficiency of an aircraft, starting with the speed and altitude of the aircraft, the weight of the aircraft, the distance flown, the mode of flight, the type and design of the aircraft, and the effect on the climate. There are also various engine modes and their performance. It also analyses how efficient aircraft engines are today and the factors that affect them. In the text, there is also a survey to compare the differences between the previous and current engines and the advantages of the current engines over the previous ones.

5.2. Research Significance

With the development of technology and the depth of research, designers can improve the efficiency of the use of aircraft fuel, this will not only greatly save non-renewable resources but also protect the environment by reducing the production of more carbon dioxide to prevent the intensification of the greenhouse effect. In addition to the fact that many airlines spend an enormous amount of money on fuel each year, this would also save them a great deal of money to do other things to improve the quality of their services and promote the development of their airlines.

5.3. Limitations and Future Study

But this post lacks the presentation of pictures, as there is no rendition of formulas or calculations in this regard. In addition, this article also has very few insufficient basic data. This can be learned through surveys and various interviews. With the advancement of modern technology and society, in the future, people can continue to improve the numerical values of aircraft fuel efficiency through continuous learning, experiments, and exercises.

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