Research on Methods of Improving Fuel Efficiency

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Abstract. In recent years, the improvement of aircraft fuel efficiency has been one of the hot topics discussed by scientists. Especially in today's increasingly tense environment of fossil fuels, how to effectively improve the fuel efficiency of aircraft engines is an important scientific problem facing us. The improvement of aircraft fuel efficiency depends not only on high-performance engines, but also on the structural design of the aircraft itself. Therefore, if the aircraft structure can be optimized, it is bound to improve the fuel efficiency of the aircraft and make it have a better flight distance in actual flight. The purpose of this paper is to illustrate ways to reduce emissions while improving fuel efficiency. A small paper airplane experiment is introduced to study the influence of wing area on speed, time, lift, drag and lift drag ratio, so as to further explore the central theme of this paper, including the analysis of many physical models. It also includes many products and ideas that engineers are now designing.

Keywords: Fuel efficiency, Fossil fuels, Aircraft engines, Structural design.

1. Introduction

Nowadays, the recourses that can be used in the world become increasingly scarce [1]. One of the resources is the fuel that is used in our daily transportation such as airplanes, automobiles, and crafts [2]. It is a serious problem for engineers to solve to reduce the use of fuel while remain the stability and safety of transportation. And this paper will focus on airplanes. When talking about airplanes, the most essential quality is security. What’s more, because of the heavy weight of the whole plane, some experts estimate that every pound of a plane’s weight, including crew, passengers, baggage, and the aircraft itself, totals up to approximately $10,000 in annual fuel costs [3]. However, it is not only about the high cost. More importantly, the amount of fuel used in a single flight is enormous, and such a large consumption in today’s resource shortage will further accelerate the depletion of energy [4]. So, by focusing on the main airfoil of the airplane, in what way can a plane minimize its fuel consumption and become more efficient to reduce the cost and save scarce resources?

The purpose of this paper is to illustrate ways to reduce emissions while improving fuel efficiency. A small paper airplane experiment is introduced to study the influence of wing area on speed, time, lift, drag and lift drag ratio, so as to further explore the central theme of this paper, including the analysis of many physical models. It also includes many products and ideas that engineers are now designing.

2. Experiments

2.1. Paper airplanes

Paper airplane is a common toy used to play when young [5]. Paper airplanes are one of the types of planes, so the experiment will be useful for the research about how airfoils affect flying and how to achieve optimal use of the fuel. It is very easy to make and control variables such as the weight, the airfoil’s shape, and the airplane's shape. This will make the experiment to be more reliable and accurate [6]. The materials for the experiment are simple and easy to obtain: a meterstick, 8 A4 papers, a paper airplane launcher like Figure 1, and a video camera [7]. It is important to use a paper airplane launcher to control the force of launching the paper airplanes each time to get more accurate data. The experiment is to determine whether the airfoils' size can affect the flight status. There are 8 different sizes of paper airplanes, and the sizes of the airfoils are 125, 120, 92, 90, 86, 77, 70, and 72 square centimeters. Each paper airplane needed to fly at least 10 times to minimize the probability to get the wrong data. The whole process of flying was recorded by a video camera [8]. Then, the videos were imported into the "Tracker", software on the computer that can track the trajectory of moving objects, to analyze the instantaneous velocity. Figure 2 shows the 8 planes that were used in the experiment.

Figure 1. Papaer airplanes launcher

Figure 2. Eight paper airplanes

2.2. Experiment conclusion

After the experiment, there is a group of data about the average time the ten planes remained in the air and the average velocity of those ten experiment planes [9]. The average velocity was calculated by excluding strange and wrong data within the experiment, so the experiment is approximately accurate. However, the external environment such as the wind will affect parts of the experiment to a certain degree. The data is shown in Table 1. The data shows that when the area of the airfoil becomes smaller, the time the plane remained in the air will become shorter at the same time, and the average velocity becomes greater while the area of the airfoil becomes smaller [10]. The reason that the paper airplane with a smaller airfoil area is that it experiences a smaller drag force. A small airfoil means the area for the plane to generate lift force is small. The lift force and drag force's magnitude always move together which means if the lift force is big then the drag force is big as well. So, lift force and drag force are proportional to the area of the airfoil. Drag force is a force that acts to slow down the plane, the direction of the drag force is opposite to the object's moving direction, so the force is doing negative work [11]. This negative work means that the total mechanical energy is decreasing. The total mechanical energy is equal to kinetic energy plus potential energy if the height of the paper airplane remains constant, then the total mechanical energy loss will cause the velocity of the plane to decrease.

Table 1. Data of the experiment

Number	1	2	3	4	5	6	7	8
Wing area (cm^2)	125	120	92	90	86	77	70	72
Time of flight (s)	2.3	2.9	2.0	2.5	1.2	1.6	1.6	1.4
Average speed (m/s)	4.8	6.3	5.1	5.0	6.5	5.7	5.0	7.1

Figure 3. Airfoil of a warplane

As a result, paper airplanes with large airfoils always can not reach a very high speed. Since the small airfoil will produce a small drag force as well as the lift force, the lift force is an important force to keep the plane to stay and be stable in the sky. So, with the small lift force, the paper airplane cannot stay in the sky for a long time. This is the main reason that paper airplanes with a smaller area of airfoils spend less time in the sky than those planes with a bigger area of airfoils. Warplanes (like figure 3) are usually with small airfoils, but with a size that can produce enough lift force to guarantee the plane will not crash. Warplanes need high speed and sensitivity, so according to the experiment of the paper airplane the area of the airfoil needs to be as small as possible. The optimal use of the fuel will be realized at the point that the lift-drag ratio is big. Lift-drag ratio is the lift force divided by the drag force. The equation of the lift force is $\frac{1}{2}C_L\rho AV^2$ and the equation of drag force is $\frac{1}{2}C_D\rho AV^2$, so the lift force divided by drag force is $\frac{C_L}{C_D}$. When the lift-drag ratio reaches a relatively big value, the use of fuel will be efficient. So, the area of the airfoil should not be very large to reduce the drag force as much as possible to increase the lift-drag ratio but is also important to have a proper size to ensure the plane can have a normal flying status.

3. Other possible methods to improve the efficiency of using fuel while flying

3.1. Winglet

The winglet is a small nearly vertical airfoil at an airplane's wingtip. The winglet is used to improve the aerodynamic effect according to figure 4. These two winglets are placed on the windward points on both sides of the wing, so the air that goes around them will generate some extra lift force that flows along the airfoil and the inside. They can improve the performance of airplanes by about 10% to 15%. The low drag force can reduce the use of fuel because on the horizontal orientation of a plane's free diagram there are only two forces—drag force and traction produced by the engine. The drag force can be balanced only by the traction. The fuel is used to produce the traction, so a small drag force will lead to a small rate of work for the engineer which will save resources and improve the efficiency of the fuel used while flying. With the winglet, the drag force will be reduced accordingly which can reduce approximately 6% of the emission.

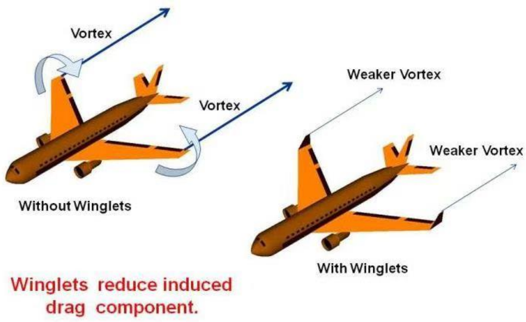

Figure 4. Winglets

3.2. CCO and CDO

CCO and CDO (according to figure 5) are two things that control the plane's ascent and descent that is controlled by AI. These two things can let the plane fly by an ideal route to realize the goal of reducing fuel combustion, reduce global gas emissions, reduce noise, and fuel costs.

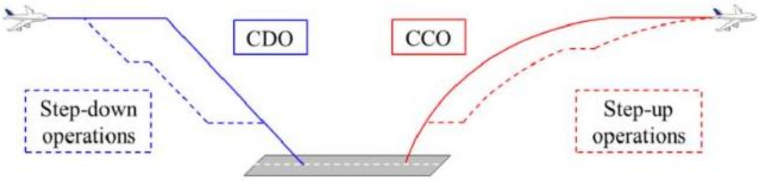

Figure 5. CCO and CDO

3.3. New kinds of materials

The aviation industry has begun to use 3D printing technology (additive manufacturing), carbon fiber materials, and shape memory alloys (SMA) (according to figure 6), as they can all reduce aircraft weight while increasing customization and overall construction efficiency. The global aerospace 3D printing market is expected to grow at a high rate of 55.85% during 2016-2020. Shape memory alloys work by heating: At the desired temperature, the alloyed metal transforms into different shapes. SMA is being developed as a shock absorber for launch vehicles and commercial jet engines. Reducing the overall weight of an aircraft has always been a top priority for improving fuel efficiency.

Figure 6. SMA

3.4. New machine—D8

In 2008, as part of NASA's N+3 program, a group of engineers from Aurora Flight Sciences, MIT, and Pratt & Whitney began working on a design concept for a commercial aircraft. They're dubbing it the "Double Bubble" D8(according to figure 7), and if the new machine works as expected, it will drastically reduce commercial aircraft noise, emissions, and fuel burn associated with business travel. Unlike other airliners, the D8 was designed without engines under the wings. Instead, the designers chose to place the engine on the top of the fuselage near the tail. This change greatly reduces drag and improves fuel efficiency. If D8 is designed and implemented as planned around the world, it has enormous potential to reduce aviation-related fuel consumption and potentially reduce emissions by up to 66% over 20 years. It will also result in 37 percent less fuel than airliners, 50 percent less ambient noise, and 87 percent less landing and circulating nitrogen oxide emissions.

Figure 7. D8

3.5. BWB

In just ten years, an aircraft with a new wing-shaped fuselage will be a reality. A scaled version of the "Hybrid Wing Body" (BWB) (according to figure 8) aircraft is currently being tested at a NASA facility. NASA says a commercial design will be realized by 2035. Some spec improvements for the BWB aircraft: 27% less fuel, 15% less weight, 20% higher lift-to-drag ratio, 27% less thrust required.

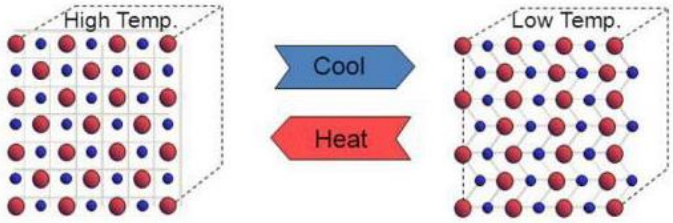

Figure 8. BWB

4. Conclusion

Although today's aircraft is already very developed, there are still many deficiencies, such as high fuel consumption (a huge consumption both economically and from the perspective of current scarce energy), and it is not conducive to the protection of the environment. The gases emitted by airplanes are serious air pollution, which will aggravate the greenhouse effect and cause global warming. People are facing the dual test of energy and environment. Engineers are now actively thinking of ways to solve the problem, whether it's from the wing or the engine, fuselage materials, and so on. Just like the influence of the size of the wing area on the flight time, speed, lift and drag discussed in this paper, changing the area and shape of the wing is also one of the solutions that can be achieved at present, it can Effectively reduce the resistance so that the power can be reduced to achieve the ultimate goal of reducing fuel consumption and emissions. With the development of various on-road electric vehicles on the market, CO_2 emissions from road traffic are undoubtedly approaching zero. In the future, new energy is the main trend of the world, and many vehicles will use new energy as the main functional raw material to provide traction. Aviation is also being innovated and tested, such as D8, and BWB. In the future, zero emissions and low energy consumption are the goals that people are pursuing. It is imperative to protect the environment. Let us join the queue to protect the environment and be responsible for the creatures around us that live on the earth with us, and even more responsible for ourselves.

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