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ANALYSIS OF THE EFFECT OF VARIATIONS IN WINGTIP AND WINGLET ADDITIONS OF AEROMODELLING AIRCRAFT WINGS ON FLIGHT PERFORMANCE AND BATTERY CONSUMPTION

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Abstract: This research develops an aeromodelling aircraft with three wing variations: wingtip, winglet fence, and blended winglet. The aircraft is designed using 3D software and built from polyfoam, with airfoils, servos, ESCs, and motors for control. Each wing type affects performance and battery usage differently. The aircraft is tested over a 5-minute flight. Wingtips improve agility and are the most battery efficient, consuming 12.60%, with battery after Used 87.4%. Winglet fences have similar manoeuvrability to blended winglets but use more battery at 14.32% and 14.61%, respectively. While winglets save energy in large aircraft, in aeromodelling with frequent manoeuvres, they consume more battery due to energy spent on maintaining stability. This study helps aeromodelling enthusiasts choose wings that match their flying needs, whether for agile manoeuvres or fast, straight flight.
Keywords: aeromodelling, battery consumption, Drone, flight test, UAV fixed wing

Introduction

Aeromodelling is an activity involving the use of miniature aircraft models for recreational, educational, and sports purposes. This sport is a branch of aerospace sports under the Aerospace Sports Association (PORDIRGA), under the auspices of the Indonesian Aero Sports Federation (FASI). Aeromodelling is becoming increasingly popular in Indonesia and has given rise to various communities. It is enjoyed by people of all ages. In addition to being a hobby and a means of enjoyment. Aeromodelling can also serve as a platform for learning, advancing scientific knowledge, and achieving excellence in the aerospace field. In Indonesia, the sport is flourishing, evident from the numerous organized competitive events. Information regarding Aeromodelling can be accessed through personal websites. To introduce this sport, interactive multimedia applications can serve as an engaging medium (Caesar, 2019).

The research conducted by Fahriza M in 2022 aimed to explore the wing's reactions through stress, displacement, and strain simulations. Based on the simulation results, it was observed that the maximum stress occurring on the Boeing 737-500 wing without winglet installation was concentrated at the engine mounting point. In the case of the wing with winglet installation, it was noted that the point of highest stress did not differ significantly from the wing without wingletsOne component of an aircraft that can affect fuel consumption is the winglet. A winglet is a component located at the wing's tip or wingtip. Its function is to slow down the meeting of high-pressure air below the wing with lower-pressure air above the wing. As a result, the airflow rotation or vortex generated by the wingtip is smaller, leading to reduced aerodynamic drag experienced by the aircraft, resulting in more fuel-efficient performance. The shape and type of winglet vary according to the aircraft's type and requirements (Maulana, 2022).

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In this study, the results indicate that the use of winglets on an aircraft's wings can lead to a reduction in induced drag by 6.66%. Induced drag is a component of the total drag generated by the wing as it produces lift. This reduction in induced drag results in a significant enhancement of aerodynamic efficiency. Furthermore, the utilization of winglets also provides benefits in fuel savings. Based on this research, the application of winglets can save up to 8% of fuel consumption. This saving occurs because winglets assist in decreasing the aerodynamic resistance generated at the wing's tip, optimize airflow around the wing, and reduce the formation of vortex at the wingtip that can increase drag. Therefore, spiroid winglets have proven to be an effective solution in enhancing aircraft aerodynamic performance and reducing fuel consumption. This finding holds important implications for the development of more efficient and environmentally friendly aircraft designs (Maulana, 2022).

With the rapid development of aeromodelling aircraft both for entertainment and hobbies, or for certain missions, the authors try to examine the effect of additional structures on the wings in the form of wingtips, winglet fences and blanded winglets on baterrey consumption, especially aeromodelling aircraft. researchers hypothesize that the type of aoreomodelling aircraft that tends to move with aggressive and agile maneuvers with a lot of acrobatic action will have a different effect from large aircraft or fixwing UAVs for surveys if added wingtip structures, winglet fences and blanded winglets.

Method

In this study, an experimental approach is employed to investigate the impact of various types of winglets on the performance of the Aeromodelling J-1B aircraft. The objective of this research is to compare the effects of using winglets versus not using winglets on the aircraft. To conduct this study, the design of the J-1B aircraft along with different types of winglets to be used is prepared using Solidworks software. The design is scaled down to match the Aeromodelling model used in this study. The use of the experimental method enables researchers to systematically and objectively test winglet variations. Each type of winglet will be installed on the J-1B aircraft, followed by testing its performance in terms of stability, speed, and efficiency.

In this study, the fixed variable or controlled variable used when collecting data is, the weight of the aeromodelling aircraft is fixed with the weight of 275 gram. With variations in aircraft wing design, there are certainly differences in lift. Therefore, to achieve a weight of 275 gram, a lead ballast is added to the body of the aeromodelling aircraft. The condition of the battery used at the time of testing was 100% (full battery) with the initial voltage of the battery used is 12.8 volts and battery charging time of about 4 hours. The flight time used to analyze the aircraft's performance and battery consumption is 5 minutes. To minimize the influence of environmental factors, flight data collection was conducted at the same time of day, namely at 14:00 WIB, even though on different days. This is expected to ensure that environmental factors, such as wind speed and direction, remain relatively consistent.

Data obtained from these tests will be analyzed to determine the impact of each type of winglet on the aircraft's performance. Thus, this research aims to provide a better understanding of the benefits of using winglets on the Aeromodelling J-1B aircraft and offer recommendations for optimal design to enhance its performance.

Figure 1. Aeromodelling aircraft design with wing variations; (a) Wingtip, (b) Fence Winglet (c) Blended Winglet

Discussion

Data Analysis

Data analysis was conducted based on a comparison between each wingtip and winglet concerning battery power consumption, which was tested on each aircraft with different wingtip shapes for 5 minutes. The following is the table of test results along with Average remaining Voltage and battery percentage after use that has been utilized.

Tabel 1. Data battery remaining and battery percentage after use

No	Wing Variations	Battery Percentage After Use (%)	Average remaining Voltage (v)			
			Data 1	Data 2	Data 3	Average
1	wingtip	87.4	11.91	12.3	9.37	11.19
2	Winglet Blended	85.39	11.53	11.29	9.97	10.93
3	Winglet fence	85.68	12.14	11.62	9.15	10.97

Analysis Flight Performance

The aeromodelling aircraft that has been made will be subjected to flight performance analysis and battery consumption tests. The wingtip, a type of wingtip design, enhances flight performance during aggressive maneuvers because it lacks the stability-imposing characteristics of winglets located at the wingtips. This wing configuration is better suited for short-distance flights. Winglets are designed to reduce induced drag by minimizing wingtip vortices (Hariyadi, 2018), which can improve fuel efficiency, increase payload, and extend flight range(Lee, Y.J., 2021). They act like end plates, reducing pressure nullification at the wingtips and diminishing adverse effects of vortices (Gatto, A., 2009)(Ramakrishnan, B., 2016). During maneuvers, the time required to turn is approximately 5 to 6 seconds when using wingtips. The flight performance of aeromodelling aircraft can be seen in Figure 2.

Figure 2. Wingtip aeromodelling aircraft performance

The winglet fence, a type of wingtip design, has flight performance that is nearly the same as blended winglets. It requires a sufficient distance to change direction due to the influence of the winglet during maneuvers, which is necessary to return the aircraft to a stable straight flight condition. During maneuvers, the time required to turn with winglet fences is between 9 and 11 seconds, which is different from wingtips which only require 5 to 6 seconds. The flight performance of aeromodelling aircraft can be seen in Figure 3.

Figure 3. Fence winglet aeromodelling aircraft performance

The Blended Winglet, a type of wingtip design, provides more stable flight performance (Sanchit, M.D., 2023). However, during short distances, aircraft maneuvering becomes more challenging. A broader distance is required for a normal change in direction. The advantage of Blended Winglets is the enhancement of aerodynamic efficiency and reduction of turbulence generated by the wingtip during long-distance flights but not in short-distance flights. During maneuvers, blended winglets require a longer time to turn, approximately between 12 and 14 seconds, while wingtips only require 5 to 6 seconds. The flight performance of aeromodelling aircraft can be seen in Figure 4.

Figure 4. Blended winglet aeromodelling aircraft performance

Of the three wingtip types, one involves adding a winglet at the wingtip. However, the use of winglets has the consequence of increased battery power consumption due to the additional power required during maneuvers caused by the winglet, forcing the aircraft to return to a normal condition. For flights over short distances, aeromodeling enthusiasts typically choose to use wingtips. This is because they seek interesting flight actions, and wingtip usage is more battery-efficient. The use of winglets is more suitable for UAVs (Unmanned Aerial Vehicles) with long missions, such as UAV cargo missions. Winglets can maintain flight stability and are more efficient in terms of battery usage when flying straight. This is because there are fewer maneuvering processes that require extra thrust from the motor. Therefore, the selection of the appropriate wingtip type depends on the flight distance, flight objectives, and specific needs of the aircraft or UAV. The use of winglets can lead to an increased load, especially for aircraft that frequently maneuver, such as aeromodelling aircraft, which may require additional power during maneuvers to maintain stability and control(Qiang, G., 2012)(Dimino, I., 2021). This can result in higher battery power consumption, especially in dynamic flight conditions (Malathi, S., 2024). Some winglet designs, such as flexible winglets or morphing winglets, can adapt to various flight conditions, potentially optimizing performance and reducing the need for additional power during maneuvers(Djahid, G., 2021)(Falcao, L., 2011).

Fixed wingtips can also improve aerodynamic performance by increasing the aspect ratio and providing gust load alleviation. They can reduce gust loads and improve load distribution, which can be beneficial for short-distance flights(Balatti, D., 2023). For short-distance flights, wingtips may be preferred due to their simpler design and lower impact on structural weight and power consumption compared to winglets. This makes them a practical choice for aeromodeling enthusiasts who prioritize energy efficiency and ease of use(Balatti, D., 2022)(Wu, M., 2021)..

Analysis Battery Consumption

From the data obtained after the flight of the aircraft aeromodelling, the Average remaining Voltage data of the battery used is obtained as seen in Figure 5.

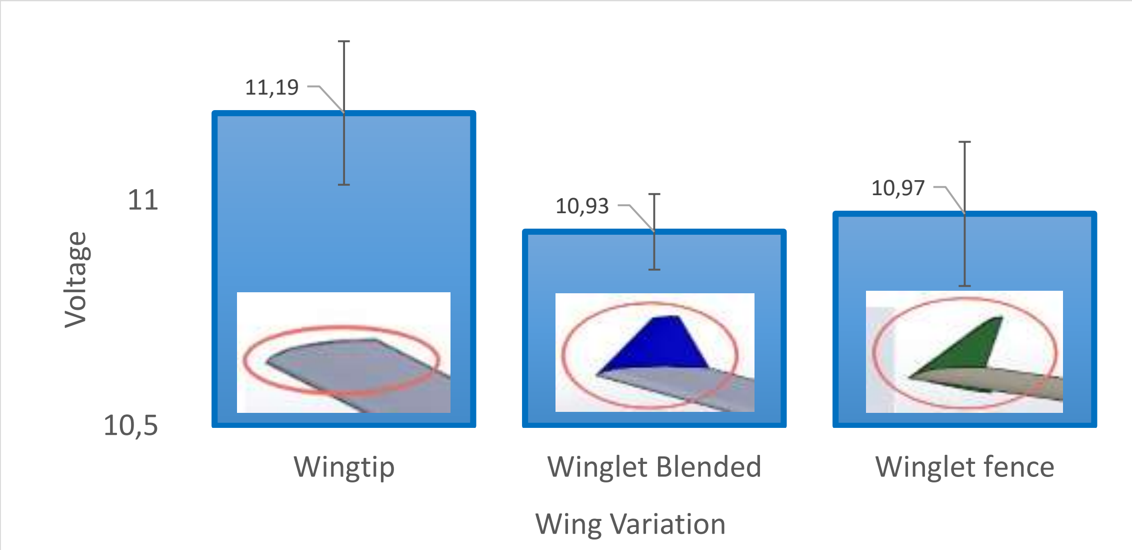

Figure 5. Average Remaining Voltage of The Battery

From the bar graph in the above figure, it can be observed that among the winglet and wingtip variations, the highest remaining battery consumption value is recorded for the wingtip variation with a value of 11.19 V, while the lowest value is obtained for the blended winglet variation with a value of 10.93 V. The value for the fence winglet variation is 10.97 V. These values are obtained based on the average of data collected every 5 minutes for three rounds of each type of wingtip, blended winglet, and fence winglet variations, based on voltage measurements.

Percentage comparison is presented to determine the power consumption relative to 100% battery or 12.80 V (voltage level). From the collected data for each variation, it can be observed that the highest power consumption is seen in the blended winglet variation, depleting the battery consumption by up to 14.61%. The lowest battery consumption based on these variations is in the wingtip variation, consuming 12.60% of the battery. For the fence winglet type, the average power consumption depletion is approximately 14.32% of the battery. The battery percentage data after use can be seen in Figure 6.

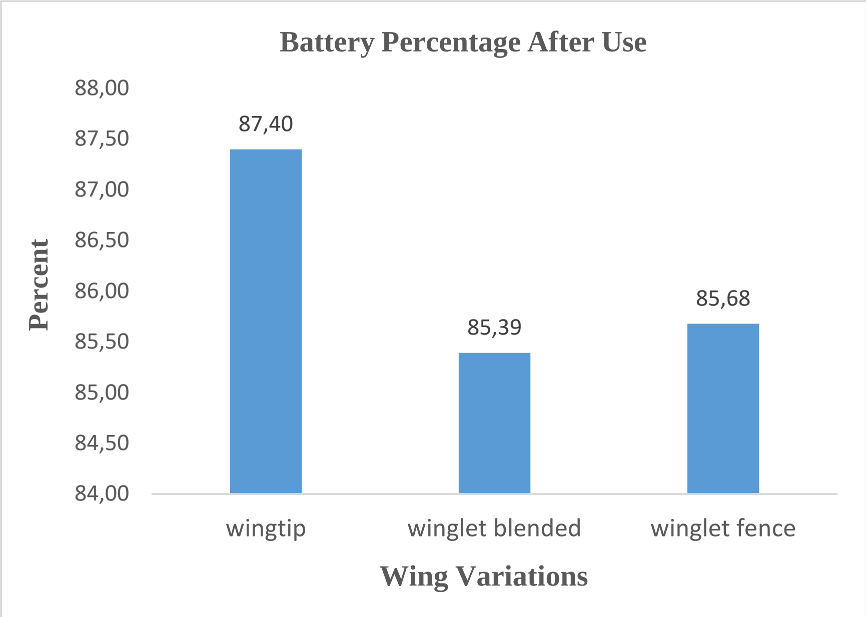

Figure 6. Battery Percentage After Use

From the image above, it can be seen that aeromodeling aircraft with wingtip wing types after flight tests have the most energy stored in the battery, which reaches 87.40%, this means that the wingtip wing type is more battery-efficient than the wing type with winglet variations. Although in wide-body aircraft the use of winglets is known to provide savings in battery consumption, but for aroemodelling aircraft types with many manoeuvres, it turns out that the use of winglets makes battery consumption more wasteful, this is because the aircraft tends to use its energy to make the aircraft in a stable condition in a straight line.

Suggestions for further researchers to develop this aircraft with stronger materials and with a more aerodynamic design. Aircraft made from carbon fiber or glass fiber are often designed without winglets (Setiaawan, 2022), so it is necessary to develop the addition of winglets and measure the resulting battery consumption.

Conclusion

The addition of winglets at the wingtip has different effects depending on their type. Wingtips provide agile flight performance during maneuvers and are more battery-efficient, making them suitable for short-distance flights with exciting flying actions. Blended Winglets enhance aerodynamic efficiency and reduce turbulence during long-distance flights but are less suitable for short distances. Winglet fences perform almost as well as Blended Winglets but with lower battery consumption. The use of winglets is more appropriate for UAV with long-range missions that require stability and efficiency, while wingtips are better suited for aeromodeling enthusiasts seeking exciting flying actions and battery savings. Although in wide-body aircraft the use of winglets is known to provide savings in battery consumption, but for aroemodelling aircraft types with many manoeuvres, it turns out that the use of winglets makes battery consumption more wasteful, this is because the aircraft tends to use its energy to make the aircraft in a stable condition in a straight line. The choice of the right wingtip type depends on the flight distance, flight objectives, and specific needs of the aircraft or UAV.

Testing was conducted on the J-1B model aircraft with wingtip, Blended winglet, and fence winglet variations. The test data included flight time, endurance time (4 hours), initial battery levels, and average remaining battery levels. From the analysis of this data, it can be concluded that the wingtip variation exhibits the lowest battery consumption, with an average remaining battery level of 11.19 V and a battery depletion percentage of 12.60%. On the other hand, the Blended winglet variation demonstrates the highest battery consumption, with an average remaining battery level of 10.93 V and a battery depletion percentage of 14.61%. The fence winglet variation shows an average remaining battery level of 10.97 V and a battery depletion percentage of 14.32%.

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