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Ratio of All Unit Weight (AUW) to Thrust force of Upper Wing Aeromodelling Aircraft

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Abstract: The aircraft used in this study is the upper wing type which has the advantage of flight stability. This upper wing aircraft was designed by the researchers themselves with three different types of wings with a wing span of 1.35m and a fuse lag of 0.925 meters. There are four main forces that work when the plane is in the air, namely lift, thrust, air resistance and gravity. From the results of this study, it can be concluded that the heavier the aircraft unit being flown, the greater the minimum thrust required to fly the aircraft. The measurement results of the 3 aircraft weights, namely 917 grams, require a thrust of 2030 grams of force, whereas for a total aircraft weight of 1,230 grams a thrust of 2510 grams is required, and at an aircraft weight of 1495 grams a minimum thrust of 3040 grams is required. The results also show that the thrust generated is not linear with the throttle position.

Keywords: Aeromodelling; All Unit Weight (AUW); Thrust Force

Introduction

The aircraft used in this study is the upper wing type which has the advantage of flight stability. This upper wing aircraft was designed by the researchers themselves with three different types of wings with a wing span of 1.35m and a fuse lag of 0.925 meters. There are four main forces that work when the plane is in the air, namely lift, thrust, air resistance and gravity. From the results of this study, it can be concluded that the heavier the aircraft unit being flown, the greater the minimum thrust required to fly the aircraft. The measurement results of the 3 aircraft weights, namely 917 grams, require a thrust of 2030 grams of force, whereas for a total aircraft weight of 1,230 grams a thrust of 2510 grams is required, and at an aircraft weight of 1495 grams a minimum thrust of 3040 grams is required. The results also show that the thrust generated is not linear with the throttle position.

The UAV aircraft or unmanned aerial vehicle was first made by Frits Gasslou which aimed to fire weapons at enemies during World War II. In its development, small-scale aircraft modeling or often referred to as aeromodelling is utilized for the benefit of actual aircraft design. The design of an aircraft that is actually large in size is then made into a miniature in a small size, which is called an aeromodelling aircraft. This aircraft was then tested to fly with a certain thrust capacity and with a control unit to test the engine thrust, maneuverability, stability and agility of the aircraft against various conditions of wind movement in flight.

At this time aeromodelling is used as an activity with the aim of entertainment (recreation), sports, education and business. Currently, aeromodelling activities can be carried out by almost all groups of people because the tools and materials used are quite cheap and affordable for all groups of people. Aeromodelling activities are divided into three categories, the first are those who play aeromodelling only for recreation or pleasure, the second as a means to

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hone an understanding of aviation science and the third as a means to achieve achievements in aerospace sports.

There are three types of aeromodelling aircraft, namely free flight aircraft, control line aircraft and remote control aircraft. Free flight aircraft are flown without the use of external control devices from the ground, the movement of the aircraft solely depends on the wind direction and initial settings. The second is an airplane with a control line which is controlled by a long rope so that the flight of the plane always surrounds the pilot controller with a trajectory radius equal to the length of the tether. The third type of aircraft is a radio controlled aircraft which is controlled by a remote control transmitter (which functions as a transmitter) which is controlled by the pilot and a receiver (as a receiver) which is placed in the aeromodelling aircraft. The control signal transmission used in this remote control is in the radio frequency spectrum.

UAV aircraft with medium and medium size for certain purposes are widely used by the public. This aircraft is often referred to as PTTA or unmanned aircraft. Initial research on this aircraft was originally intended for defense and security systems. In its development the use of PTTA is widely used for the use of cameras for the art of photography and the use of cameras and various sensors for earth surveys. Other uses are as tools and instruments for assistants in agriculture, for example for spraying pests or spraying various types of fertilizers. Hermanto, in 2018 made a tool to measure the thrust force of brushless motors, the results of his analysis show that the drag force depends on two factors, namely the type of electric motor and the type of propeller. Putra et al., in 2019 made computer-based interactive media to introduce aeromodelling activities. Anggriawan 2014, conducted research on the relevance of Aeromodelling extracurricular material, using a descriptive method. Nugraha and Kushartanti in 2018 conducted research on the effectiveness of aeromodelling training. Rokhmana in 2013 conducted mapping using UAVs. Rokhmana in 2013 conducted research on accelerating cadastral mapping using unmanned aerial vehicle technology. Suryasaputra et al in 2014 used UAVs for aerial photography purposes through the Aeromodelling And Payload Telemetry Research Group (APTRG). Miraza and Isranuri in 2012 analyzed the stresses in a model airplane wing. Majid, et al in 2015 identified a model of the Bixler type fixed-wing unmanned aircraft.

The design and manufacture of aeromodelling aircraft is closely related to the application of physics. There are 4 main forces acting on an airplane during flight. The first force is the thrust of the aircraft (thrust force) which is the forward direction force generated by the propeller driven by the engine or jet engine. The second force is the drag force due to air friction (drag force) which is the resistance force which is the result of friction between the wings, fuselage, stabilizer and other parts of the aircraft. The third force is total weight (all unit weight), which is the total weight of the aircraft, including fuel, passengers, and other goods on board. The 4th force is the uplift force which is the result of the lift arising from the difference in aerodynamic pressure on the surface of the upper and lower wings. The problem to be examined in this research activity is how is the ratio of all unit weight (AUW) to the thrust of aeromodelling aircraft.

This study aims to determine the ratio of all unit weight (AUW) to the thrust of aeromodelling aircraft. The greater the value of the ratio, the more efficient the aircraft is in transporting heavy loads. The ratio of all unit weight (AUW) to the thrust of an aeromodelling aircraft is a technological innovation that will help improve the lift capability of the model to carry out various technical purposes such as carrying camera loads, pest spraying, sensor carriers and other survey purposes.

The plane can fly because of the lifting force of the airplane wing which is the result of the pressure between the air below minus the wing and the air above the wing. This pressure difference arises because of the difference in the velocity of the airflow above and below the wing caused by the cross-sectional shape of the wing or better known as the airfoil. The higher the difference in speed above the wing and under the wing, the greater the lifting force of the plane's wing.

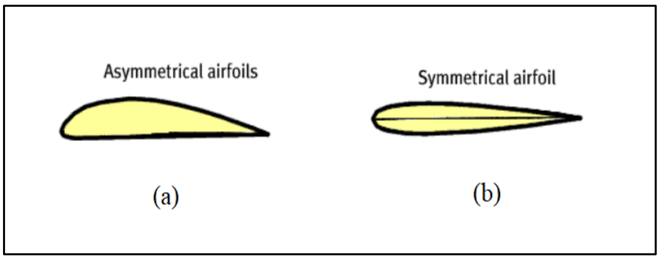

Figure 1. (a) Asimetrical Airfoil (b) Simetrical Airfoil

This big speed difference is obtained from the airfoil which forms an asymmetry at the top with the bottom. This asymmetrical airfoil tends to be widely used in commercial aircraft because of its advantage in large lift forces. The weakness of this asymmetrical airfoil is that there is a large drag force which inhibits the plane's speed so that its speed becomes more limited. Aerobatic aircraft usually use a symmetrical airfoil with the shape of the upper wing more or less the same as the lower wing so that the difference in speed is not too high so that the lift force is not too large. The advantage of this symmetrical airfoil is the small drag force, so the plane's speed becomes bigger. Aerobatic aircraft also require much greater thrust from the engine than commercial aircraft of the same size.

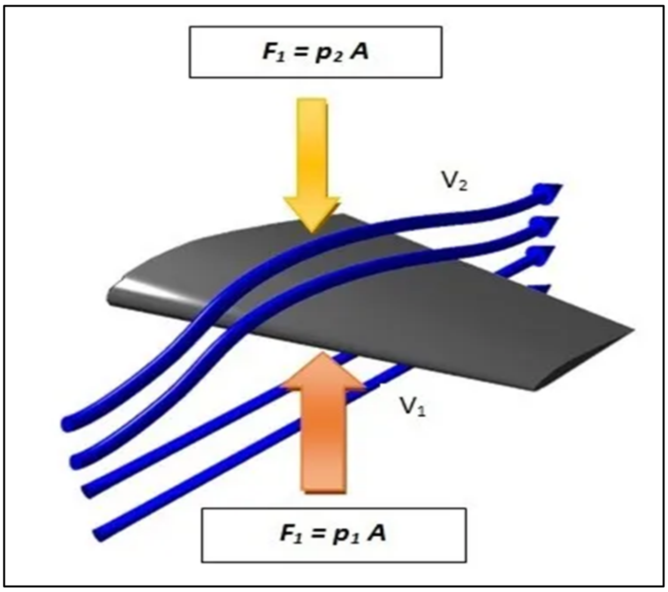

Figure 2. Air flows over aircraft wings surface

The formulation of the magnitude of the wing lift can be derived from the Bernoulli equation with the Equation 1:

$$pa + \rho g ha + 1/2 \rho va2 = pb + \rho g hb + 1/2 \rho vb2 \quad (1)$$

where pa is the air pressure above the wing, ρ is the density of the air, g is the gravity of the earth, ha is the altitude of the wing, vb is the air speed at the bottom of the wing, pb is the air pressure under the wing, hb is the altitude of the wing. Assuming the value of ha is almost the same as the value of hb , the pressure difference between the bottom and the top of the wing can be formulated as Equation 2:

$$pb - pa = 1/2 \rho (va2 - vb2) \quad (2)$$

From equation 2, with the value k = va / vb , while vb is considered equal to the speed of the aircraft, the final result of the aircraft's lift force is obtained which is the multiplication of the wing area (A) with the difference in the pressure below and above me as follows (Equation 3):

$$F = 1/2 \rho (k2 - 1) v2A \quad (3)$$

From this formula it can be seen that the lift of the aircraft depends on the area of the wing (A) the shape of the airfoil symmetry which affects the value of the constant k, the speed of the aircraft (v) and the density of air passing through the wing.

Upper wing aircraft is an aircraft with wings above the fuselage. The advantage of this aircraft is high stability because the center of gravity of the aircraft is under the wing. Upper wing aircraft are generally dominated by propeller-engined aircraft with relatively small thrust. Upper wing aircraft are often used as training aircraft for reasons of stability.

Aeromodeling airplanes are small airplanes which are models of real airplanes. Initially this model aircraft was used in designing and testing real aircraft. The trial of this model aircraft is used as a reference as a basis for making aircraft in actual size. In its development, Aeromodelling is used as an activity with the aim of education, recreation, sports and business. At first, aeromodelling activities were only attended by certain circles, because the equipment at that time was still relatively expensive. At this time Aeromodelling activities can be participated by various levels of society, due to technological developments that have made various aeromodelling aircraft components easy to manufacture at quite low prices.

There are three types of aeromodelling aircraft that are commonly made, namely free flight, line control, and remote control aircraft. Free flight aircraft are flown without using external controls from the ground level. The movement of this free flight aircraft solely depends on the initial setting, as well as wind speed and direction. The second aeromodelling aircraft is a control line aircraft which is controlled by a long rope, so that the flight of the aircraft always surrounds the pilot who controls it with a rope. The third type of aeromodelling aircraft is a remote control aircraft which is controlled with a remote control transmitter in the pilot's hand and uses a receiver placed inside the aircraft. The control signal transmission on this remote control is digital based and is on the radio wave spectrum with a frequency of 2.4 GHz.

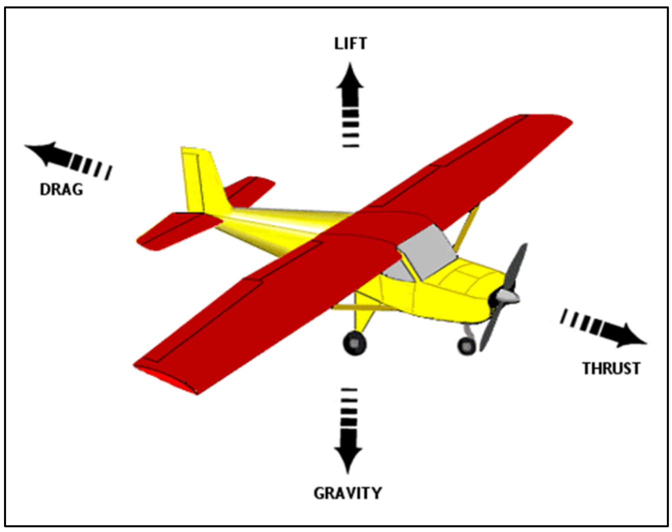

Figure 3. Thrust, lift, air resistance and weight acting on an airplane while flying

Aeromodeling aircraft with small, medium and medium sizes are widely used by the public for certain purposes. This aircraft in English is called a UAV or unmanned aerial vehicle, or in Indonesian it is often called a PTTA or unmanned aircraft. At first the initial research of this aircraft was intended for defense and security systems. However, in its development the widespread use of PTTA has been dominated by the use of cameras for photographic art (footage) and the use of cameras and other sensors for earth surveys. Other uses are as supporting tools and instruments in agricultural production, for example spraying fertilizers or spraying pests. Research on aeromodelling has been carried out by several previous researchers. Hermanto, in 2018 made a tool to measure the tensile force of a brushless motor, the results of his research analysis show that the tensile force depends on the type of electric motor and the type of propeller used. Putra et al. in 2019 made interactive media in the context of introducing aeromodelling activities. Anggriawan 2014 conducted aeromodelling research to describe the relevance of aeromodelling extracurricular material to established standards, using a descriptive method. Nugraha and Kushartanti 2018, conducted research on the effectiveness of an aeromodelling training. Rokhmana, in 2013 conducted mapping using PTTA. Rokhmana, in 2013 researched the acceleration of cadastral mapping using unmanned aerial vehicle technology. Suryasaputra et al., in 2014 used PTTA for aerial photography purposes with the Aeromodelling and Payload Telemetry Research Group (APTRG). Miraza and Isranuri, in 2012, analyzed the stress on aeromodelling airplane wings. Majid et al., in 2015 identified a model of the Bixler type fixed wing unmanned aircraft.

Method

This study aims to determine the relationship between the minimum thrust of the upper wing aircraft and the overall weight of the aircraft, so that the upper wing aircraft can perform basic maneuvers, namely looping, rolling maneuvers, and vertical maneuvers.This research was carried out through several stages, namely the first planning of aircraft design, making model aircraft KIT, selection and installation of propulsion engines, data collection, measurement of engine thrust and data analysis and processing. The design of the aircraft was carried out by 5 researchers consisting of 1 chief researcher and 4 members, at the basic physics laboratory at the University of Mataram.The manufacture of the aircraft was carried out by researchers and assisted by several students from the Basic Physics class with active status in the current semester who were supervised intensively by the researchers directly. The selection of the machine and its supporting components was carried out by 5 researchers while the installation of the machine was carried out by several students and technicians under the supervision of the researchers.

The measurement of the ratio of thrust to the weight of the aircraft was carried out at the former Mataram Selaparang airport. The measurement of the engine thrust was carried out at the basic physics laboratory at the University of Mataram. Analysis of the data that has been taken is carried out by the lead researcher which is then reported in an accredited national scientific journal. Aeromodelling aircraft have the exact same working principle as real airplanes. The physical factors that are very important in the existence of real aircraft and aeromodelling aircraft are the forces acting on the aircraft. There are four main forces acting on the plane, the first is the thrust or thrust, the second is the air resistance or drag force, the third is the lift or up lift and the fourth is the weight of the aircraft or all unit weight (auw). This study aims to determine the relationship between the minimum thrust of the Upper wing aircraft and the overall weight of the aircraft.

The lift of the aircraft is generated by the shape of the airfoils on the wings which have an impact on the airspeed below and above the wings. There are two kinds of airfoils on airplanes, namely asymmetrical airfoils and symmetrical airfoils. An asymmetrical airfoil has the advantage of being a large lift force but with the disadvantage of being a large air resistance force. This air resistance causes aircraft with asymmetrical airfoils to have lower speeds compared to aircraft with symmetrical airfoils. The advantage of a symmetrical airfoil is that it has a small drag force or air resistance, but has a weakness, namely a small lift, so that a symmetrical airfoil is suitable for aircraft with light loads but at high speeds.

This research was conducted in several stages, namely the design and manufacture of upper wing aircraft, determination of center of gravity (CG), measurement of aircraft flight weight, measurement of aircraft thrust, initial flight trials, and basic maneuver trials. This aircraft was designed by the author without using plans from existing aircraft, meaning that this aircraft has never been made before on the same scale. The overall length of the aircraft from nose to tail is 92.5 cm, while the wingspan is 135 cm.

The upper wing type aeromodelling aircraft that has been made and tested in this study is shown in Figure 4. The flight weight (all unit weight) of this aircraft is 917, 1230 and 1495 gram force which is equivalent to 9.170 N, 12.30N and 14.95 Newton using the assumption that the acceleration due to gravity is 9.8 m/s2. The Electronic Speed Controller (ESC) used has a current supply of up to 40 Amperes. The servo as the stabilizer actuator used is type 9G, while the main drive motor uses the Turnigy brand with the D2826/6 series with a rotation constant of 2200 KV. The remote control used is the Flysky I-6 brand. Flying weight measurement is done by weighing the overall weight of the aircraft which consists of polyfoam, brushless motor, electronic speed controller (ESC), transmitter, servo, pushrod and battery. The AUW variation is obtained by changing the battery used, namely Li Polymer 3S, 1200 mAh, Li Ion, 3s 1500 mAh and Li Po 3s, 2100 mAh.

Measurement of aircraft thrust was carried out using a digital scale as shown in Figure 5. The minimum thrust for each AUW was obtained by reducing the throttle without reducing the pitch boost until a stall occurred as indicated by the aircraft starting to roll and losing altitude. In this condition, the throttle position is recorded to test the thrust as soon as the plane reaches the bottom and is saved by gliding. Efforts to get this stall condition are carried out by flying straight without changing the pitch which is obtained without touching the right rudder control on the remote. If the right control on the remote, namely the pitch is changed, then the plane will glide and no stall will occur even though the thrust is turned off.

Figure 4. Upper wing wing aeromodelling aircraft that has been tested.

Figure 5. Measurement of the thrust force of a brushless motor with the SF-400 digital scale.

Measurement of the electric motor thrust is carried out with a digital scale SF-400 series with a maximum capacity of 10 kg as shown in Figure 5. When weighing, it should be noted that all units must be properly attached to the scale so that the battery, receiver, motor mount must be temporarily glued to the stand. scales so that when a push occurs the position does not change so that it does not affect the measured thrust. The cable also must not touch the outside of the scale so as not to reduce the rated thrust. The brushless motor is intentionally positioned at a sufficient height to be able to take air with sufficient space to be similar to flying conditions, so that the thrust is measured more accurately. The advantage of the SF-400 series digital scales is that when it is turned on under a load, all loads are corrected, so that the numbers show a zero reading, so that the boost that is measured when loading is carried out is the additional load after the weighing instrument is turned on.

Results and discussion

The measurement of the weight of this aircraft was carried out using a digital scale type SF-400 with a measurement result of 426 grams. The measurement of the thrust force of the brushless motor is also carried out with the same digital balance. From the experimental results with 3 different weights, 3 different thrusts were obtained, as shown in Table 1.

Table 1. Experimental results between the total weight of the aircraft and the minimum thrust

Total weight (grams)	Thrust (grams f)
917	2030
1230	2510
1495	3040

The measurement results with different throttle positions produce thrust as shown in table 2. The measurement results in table 2 show that the thrust is not linear with the percentage of throttle position. This non-linearity occurs because the settings on the remote control are set to give the pilot a sense of comfort when flying the aircraft. The accuracy of measuring throttle movement on the remote control is also relatively high due to limited visibility.

Table 2. Thrust generated by throttle position

Throttle (error 5 %)	Thrust (error 30 N)
35	2030
50	2510
65	3040

Table 2 shows the amount of thrust generated by the throttle with different percentages. The D2212/6 brushless motor has a diameter of 22 mm and a motor thickness of 12 mm with a constant rotation of 2200 KV, which means that every 1 volt increase in voltage results in an increase in rotational speed of 2200 RPM. The propeller (propeller) used uses a type of 2 blades with a diameter of 6 inches. From table 2 it appears that the amount of thrust generated by the motor is not linearly proportional to the amount of throttle given.

The first trial of this aircraft was carried out at Selaparang airport, Rembiga Mataram. The purpose of this test is to determine the accuracy of the center of gravity (CG) position which determines the stability of aircraft flight. The initial determination of the location of the CG is done by pushing the aircraft by hand so that it flies horizontally. If in this test the attitude of the aircraft tends to nose down, it means that the position of the CG is too forward so that the load must be added to the rear of the aircraft. If in this test the attitude of the aircraft tends to look up (nose up), it means that the position of the CG is too far back, so the load must be added to the front of the aircraft. The thrust test was carried out in the Jempong Baru field, northwest of Tugu Mutiara, Sekarbela sub-district.

Conclussion

From the results of this study it can be concluded that the heavier the aircraft unit being flown, the greater the minimum thrust needed to fly the aircraft. The measurement results of the 3 aircraft weights, namely 917 grams, require a thrust of 2030 grams of force, whereas for a total aircraft weight of 1,230 grams a thrust of 2510 grams is required, and at an aircraft weight of 1495 grams a minimum thrust of 3040 grams is required. The results also show that the thrust generated is not linear with the throttle position. This is because the throttle setting is made to be as comfortable as possible for the pilot to maneuver the aircraft. The accuracy obtained in the throttle measurement is not optimal because the remote reading is not correct because the throttle position is difficult to see. This can be overcome by continuously videoing the throttle position on the remote when the aircraft is in a stall.

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