PAPER • OPEN ACCESS

Wing design of uav serindit v-1

To cite this article: K Anuar *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **539** 012002

View the article online for updates and enhancements.

Wing design of uav serindit v-1

K Anuar[1], M Akbar[1] and Herisiswanto[1]

[1] Department of Mechanical Engineering, Universitas Riau, Indonesia

Email: kaspul.anuar@lecturer.unri.ac.id

Abstract. UAVs are controlled aircraft without the presence of pilots in them. In its use, UAVs have been used for both military and civilian purposes. In the field of plantations, UAVs are used for mapping and monitoring (survey) of an area such as areas of industrial plantations, oil palm plantations and areas of forest fire disaster in a timely and precise manner. To develop a UAV capable of carrying out the mission of mapping the coastal estate's area, in this research is done wing design UAV which is named serindit V-1. The design process begins with the design concept, then proceed with a preliminary design that aims to determine the dimensions and initial configuration of the wing UAV serindit V-1. Furthermore, the wing UAV serindit V-1 is simulated on XFLR5 software using Clark's airfoil, GOE 611 and S7055. Simulations were performed to see the characteristics of aerodynamic at takeoff speed (12 m / s), cruising speed (20 m / s) and maximum speed (30 m / s). Simulation result at the take-off speed and cruising speed show the lift coefficients produced by the three airfoils meet the requirements. Then, the highest value of the lift coefficient ratio to the air drag coefficient at cruising speed, produced by airfoil S7055 at a 3-degree angle of attack. Furthermore, the graph of the pitching moment coefficient on all angles of attack produced by the three airfoils shows a negative gradient. This shows the condition of wing stability in the pitching direction.

1. Introduction

Unmanned Aerial Vehicle (UAV) is a controlled aircraft with no pilot in it [1]. In control, it can be done manually via a radio wave transmitter or independently (autopilot) using a small computer device. Initially, UAV is only used for military purposes. One of its uses is as a target plane shooting in war exercises. However, as the development of UAV technology in the world, the use of UAV began widely used for civil purposes [2]. UAVs are utilized in the mission of mapping and monitoring of an area such as natural forest areas, industrial plantation areas, palm oil plantations and timely areas of forest fire disaster and precision. Excess UAV in performing this mission compared to the image displayed satellite is not the occurrence of image distortion due to the influence of cloud cover. With the ability of UAVs to fly under clouds, it allows UAVs to carry out mapping and surveillance missions in a detailed and clear area.

Utilization of UAV in the realm of Riau Province, Indonesia, began to be used both government agencies such as the Regional Disaster Management Agency (BPBD) Riau as well as private parties engaged in plantation industry and palm oil plantations. BPBD Riau utilizing UAV in the monitoring mission of forest fire disaster. While the private sector utilizes UAV not only on monitoring missions of forest fires but also began to be used for mapping missions and monitoring of industrial timber plantations. This breakthrough is able to reduce operational costs in terms of mapping and monitoring of industrial forest areas that previously used helicopters.

The use of UAV for civilian purposes in Riau Province has the potential to grow because Riau Province is the province with the largest oil palm plantation area in Indonesia with a total of 2,381,895 hectares [3]. Then Riau Province also has a large industrial timber plantation area (HTI) with a total of 1,673,060 hectares.

2. Fundamental Theory

2.1 Lift Force On Aircraft

While the airplane on the air, there are four forces that work, the lift, gravity, thrust, and air dry [1]. The lift force acting on the aircraft is produced due to the difference in pressure on the upper surface and the underside of the wing. The magnitude of the raised force is influenced by the wing surface area, the air type, the aircraft velocity relative to the air, and the lift coefficient. Mathematically, the correlation can be seen in the following equation [1]

$$F_l = \frac{\rho.c_l.A.V^2}{2} \tag{1}$$

2.2 Wing Typical Design

The UAV used for mapping is designed to have maximum flight range. To get a UAV that has a maximum flight range with efficient power usage, the value of the lift-drag ratio is a factor highly considered by a UAV designer [4]. Then the next factor that needs to be evaluated is the value of Reynold number. In relatively small UAVs, the airflow that operates along the UAV wing generally works on low Reynolds value. The low Reynolds number value causes the maximum lift coefficient generated by the wing is difficult to achieve [4]. The following is shown in equation 2 to determine the Reynold number [5]

$$Re = \frac{\rho.V.c}{\mu} \tag{2}$$

2.3 Basic Design of Wings Geometry and Tail of UAV

One factor to consider in determining the geometry of the wings is wing loading. In a planned UAV flying at relatively low speeds, the required wing loading value is 4kg / m^2 - 5kg / m^2 [6]. Wingloading can be determined using the following equations [6]:

$$Wing_l = \frac{m}{A} \tag{3}$$

$$A = s \, x \, c \tag{4}$$

In designing a horizontal tail, the initial dimension of a span and its surface area can be determined using the basic rules of aircraft design. The size of the horizontal tailed span is generally a quarter of the wingspan, while the size of the horizontal tail area is one-fifth of the wing's area [4]. The dimensions and position of the horizontal tail will affect the pitching stability of an aircraft. In order for a horizontal tail UAV capable of making attitude UAV stable in the direction of pitching, then the value of horizontal tail volume coefficient (Vh) usually ranges from $0.3 \leq Vh \leq 0.6$ [7]. The value of the horizontal tail volume coefficient can be determined by using equation as follows [8]:

$$V_h = \frac{A_h \, .l_h}{A \, .c} \tag{5}$$

Furthermore horizontal tail volume coefficient also affects the position of the neutral point and the position of the center of gravity (CG) of UAV. To determine the position of the neutral point and the center of gravity of the UAV can use equations as follows [7]:

$$\frac{x_{np}}{c} = \frac{1}{4} + \frac{1+\left(\frac{2}{AR}\right)}{1+\left(\frac{2}{AR_h}\right)}\left(1 - \frac{4}{AR+2}\right)V_h \tag{6}$$

$$SM = \frac{Xnp - Xcg}{c} \tag{7}$$

The vertical tail volume coefficient (Vv) of the UAV has an important role in maintaining the stability of the yawing direction. The effectiveness of the vertical tail function can be achieved if the value of the vertical tail volume coefficient (Vv) is in the range of values between 0.02 to 0.05 [7]. The value of the vertical tail volume coefficient can be determined by using equation as follows [8].

$$V_v = \frac{A_v \, l_v}{A \, c} \qquad (8)$$

3. Methodology

3.1 Design Concept UAV Serindit V-1

The design of a UAV concept is based on the UAV / design requirement object's mission. In this research, UAV serindit V-1 is designed to be suitable for mapping missions and coastal area cultivation. In accordance with its mission, the UAV serindit V-1 is designed to refer to a type of UAV glider with high-wing configured wings. The following table 1 shows the parameters of UAV Serindit V-1 as defined in this research.

Table 1. Parameter of UAV Serindit V-1

Parameter	Requirement
MTOW	1 kg – 1,5 kg
Wing Loading	5 kg/m^2
Wingspan	1,5 m
Wide Area	0,3 m^2 – 0,35 m^2
Wing Chords	0,2 m – 0,25 m
Stall Speed	10 m/s - 12 m/s
Cruise Speed	20 m/s – 23 m/s
Maximum Speed	26 m/s – 30 m/s
Flight Time	10 minutes – 15 minutes
Material	Composite and foam

3.2 Preliminary design of UAV Serindit V-1

In the initial design phase, the configuration of the wing's UAV serindit V-1 selected high wing type with a sweep angle of 5^0. The high wing configuration is selected because the lateral stability is better than other configurations. Furthermore, the initial dimensions of the wing and tail of the UAV serindit V-1 are calculated using the basic rules of aircraft design. All of the initial dimensions of the wings and the tail of the UAVseridnit V-1 will be used as parameters in the simulation process of XFLR5 software. Using equations (3) through (8), the calculation result of the initial dimension of the wing and the tail of the UAV serindit V-1 is shown in table 2 below.

Table 2. Initial dimensions of the wing and tail of the UAV Serindit V-1

Parameter	Area	Chord	Span	Volume Coefficient
Wing Dimension	0.3 m^2	0.2 m	1.5 m	-
Horizontal Tail Dimension	0.06 m^2	0.16 m	0.375 m	0.55
Vertical Tail Dimension	0.03 m^2	0.16 m	0.188 m	0.035

After determining the configuration and initial dimensions of the wing's UAV serindit V-1, then the wing design of UAV Serindit V-1 drawn on solid work software. Here is shown figure 1 wing design of UAV Serindit V-1.
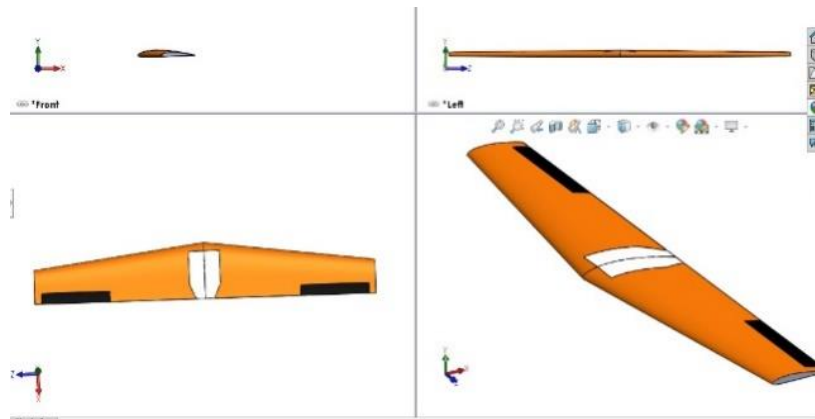

Figure 1. Wing Design of UAV Serindit V-1

3.3 Centre Of Gravity's (CoG) Design of UAV Serindit V-1
The position of the neutral point and the CG point of the UAV Serindit V-1 in the longitudinal direction is determined by equations (4), (5) and horizontal tail values of 0.55. Where the position of the neutral point and the CG point of UAV serindit V-1 based on the calculation respectively 9.35 cm and 6.35 cm.

3.4 Minimum and Maximum of Reynolds Number
One of the important parameters to determine its value is the Reynolds number. This number will be one of the parameters to be included in the simulation process in XFLR5 software. In determining the Reynolds number, the data relating to the air condition is adjusted to the coastal estate's area. UAV is planned to fly at an altitude of 100 meters above sea level. Where the air density parameter (ρ) is set at 1.177 kg / m3, the temperature (T) is 28^0 C and the air viscosity (μ) is 1.846 x 10^{-5} kg/m.s. Using equation (2) and air condition at an altitude of 100 m above sea level, the result of the Reynolds number calculation is shown in table 3 below.

Table 3. The result of calculation of Reynolds number on wings of UAV Serindit V-1

Flight Mode	Speed (m/s)	Reynolds Number
Take Off	12	$1.53 x 10^5$
Cruise Speed	20	$2.55 x 10^5$
Maximum Speed	30	$3.826 \ x 10^5$

3.5 Lift Coefficient Design
The calculation of the minimum lift coefficient is required by the vehicle of the UAV Serindit V-1 at take-off and at cruise speed. Using equation (1), the calculated value of the minimum lift coefficient required by the UAV Serindit V-1 at take-off and at cruise speed is shown in table 4 below.

Table 4. The value of the minimum lift coefficient (Cl) needs

Flight Mode	Speed (m/s)	Angle of Attack	Cl
Take off	12	8^0 - 20^0	0.5788
Cruise	20	0^0 - 3^0	0.208
Maximum	30	0^0 - 3^0	0.09

3.6 Wing Airfoil design of UAV Serindit V-1
The wing design of UAV Serindit V-1 is done with the selection of three flat bottom airfoils namely Clark y, GOE 611 and S7055 [9]. This airfoil is suitable for UAV glider type because it has the ability to stay floating when the motor drive is turned off. Here is shown figure 2 type airfoil used on wing design of UAV Serindit V-1 [9]
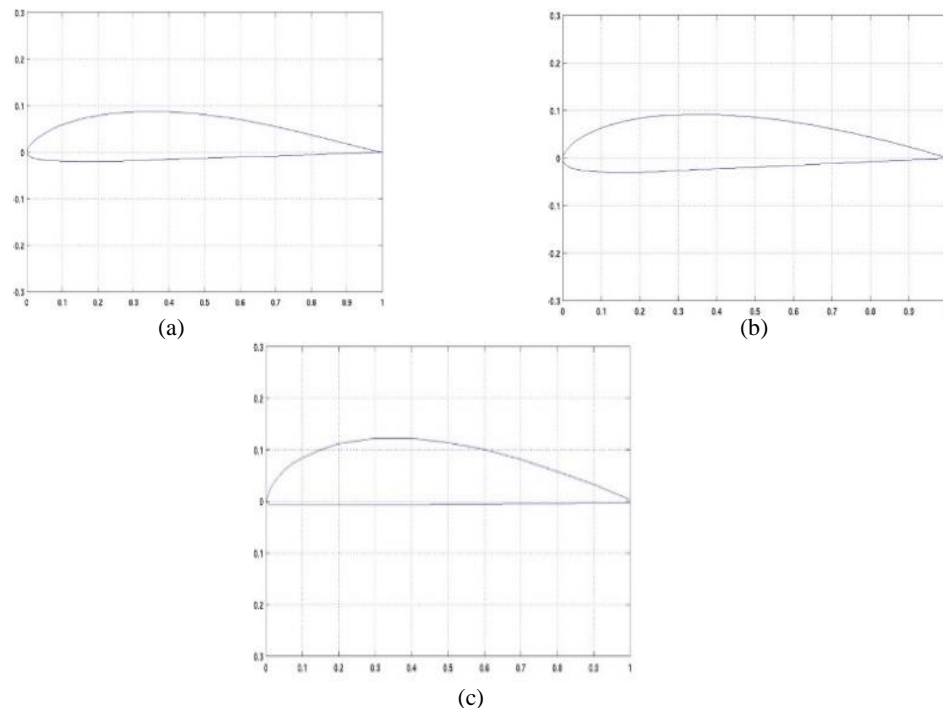

(a)

(b)

(c)

Figure 2. (a) airfoil Clark Y, (b) airfoil S7055, (c) airfoil GOE 611

4. Result And Discussion

4.1. Comparing simulation results and experiment result
Software xflr 5 is a software that is widely used to simulate aerodynamic characteristics of a UAV. In Figures 3 and 4, there is a relation between experiment result of lift coefficient vs alpha of airfoil S7055 [10] with the simulation result of software xflr 5. In figure 3, show that experimental result of lift coefficient vs alpha at Reynolds number equal to 60,000, has a trend value almost equal to the xflr5 result of lift coefficient vs alpha at the same Reynolds number.
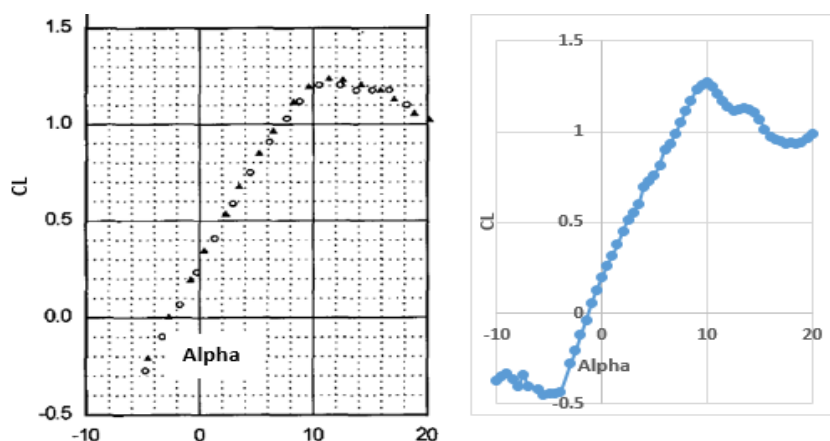

Figure 3. Lift Coefficient Vs Aoa (a) experiment [10] (b) XFLR5

Experiment result of lift coefficient vs alpha on airflow with Reynolds number of 300,000, also has a trend value similar to XFLR 5 simulation results. This graph is shown in Figure 4, where the left is a graph of airfoil S7055 obtained through experiment [10], whereas the right is a graph obtained through XFLR5 simulation.
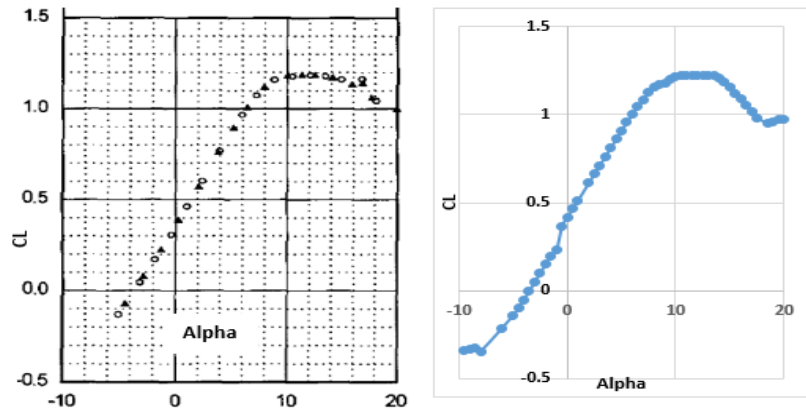

Figure 4. Lift Coefficient Vs Aoa at Reynolds number 300,000 (a) experiment [9] (b) XFLR5

4.2 Wing simulation result of UAV Serindit V-1 at takeoff speed (12 m/s)
To simulate the three airfoils with XFLR5 software, Operational speeds at takeoff and cruise speed are designed 12 m/s and 20 m/s respectively. Other conditions required are airflow conditions at an altitude of 100 meters above sea level such as air density (ρ) is 1.177 kg / m^3, temperature (T) is 28^0 C and air viscosity (μ) is 1.846 x 10^{-5} kg/m.s The following shows graphs of simulation results of UAV Serindit V-1 at take-off speed (12 m/s).
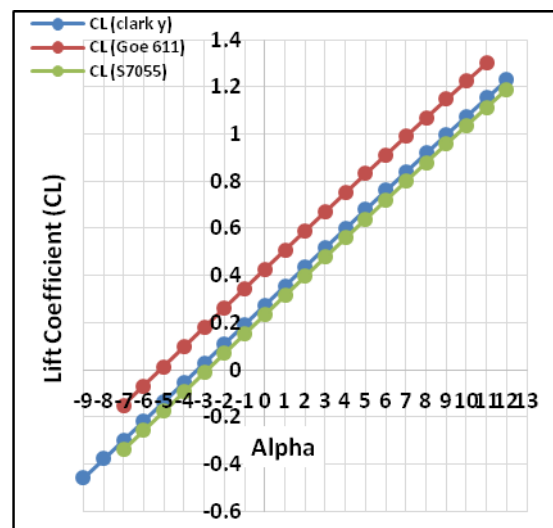

Figure 5. Lift coefficient vs Alpha graph at speed 12 m/s

The wing simulation result of UAV Serindit V-1 in Figure 5 shows the three types of wing airfoil UAV Serindit V-1 capable of producing lift force coefficient (Cl) more than 0.5788 at an 8-degree angle of attack. This shows that the lift coefficient of the three airfoils at an angle of attack of 8 degrees sufficient to lift the plane at take-off. From the graph also seen, the lift coefficient trends generated by the GOE 611 airfoil are greater than Clark airfoil or S7055 airfoil.
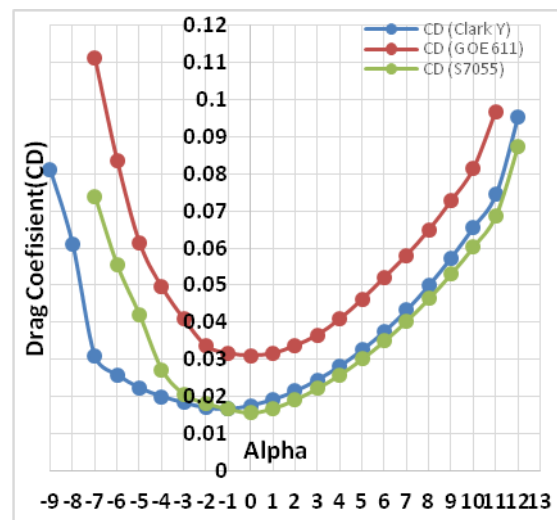
Figure 6. Drag coefficient vs alpha at speed 12 m / s

Figure 6 shows the coefficient of drag force coefficient at an angle of attack of 8 degrees occurring on the Clark Y, Goe 611 and S7055 airfoils respectively valued at 0.049, 0.064 and 0.046. When viewed as a whole at a positive angle of attack, the greatest airborne drag coefficient trends occur on the Goe 611 airfoil followed by Clark Y airfoil and S7055 airfoil.
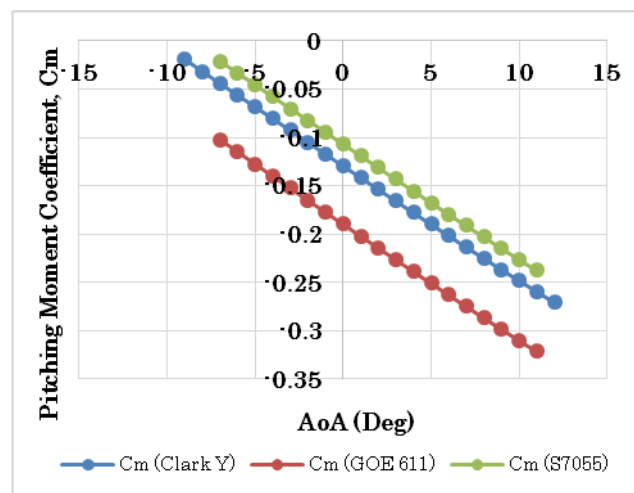

Figure 7. The pitching moment of the coefficient (cm) vs. alpha at speed of 12 m/s

The simulation results of the pitching moment coefficients of the three types airfoils as shown in Figure 7 show the pitching moment coefficients at all angles of the attack (AoA) having a negative gradient. This trend indicates good stability of the pitching direction of the wing UAV Serindit V-1 in all angle of attack conditions.
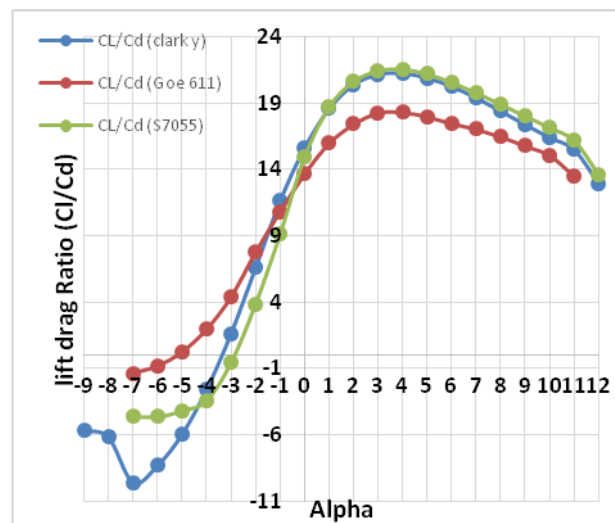
Figure 8. Lift drag ratio (Cl/Cd) vs alpha at a speed of 12 m/s

Figure 8 shows the graph of the lift drag coefficient ratio (glide ratio) at all angle of attack. The graph shows that the largest glide ratio at the positive attack angle produced by the S7055 airfoil, followed by the Clark Y airfoil and GOE 611 airfoil. The glide ratio value of the UAV will affect the duration and flight range of a UAV.

4.3 Wing Simulation Results of UAV Serindit V-1 at Cruise Speed (20 m/s)
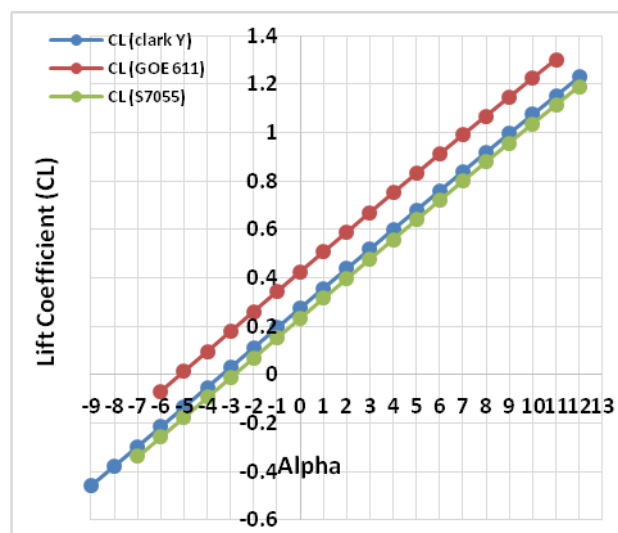The following graph shows the wing simulation results of the UAV Serindit V-1 at cruise speed (20 m/s).

Figure 9. Lift coefficient vs Alpha at speed 20 m/s

The wing simulation results of UAV Serindit V-1 at the cruise speed (20 m/s) as shown in Fig. 9 shows the three types of airfoil UAV Serindit V-1 capable to produce lift coefficient of more than 0.208 at an angle of attack of 0 degrees. This shows that the lift coefficient of the three airfoils at the angle of attack of 0 degree meets the requirements to maintain its flying height. From the graph also seen, the trend value of lift coefficient produced by three airfoils at cruise speed equal to trend lift coefficient which resulted at take-off speed.
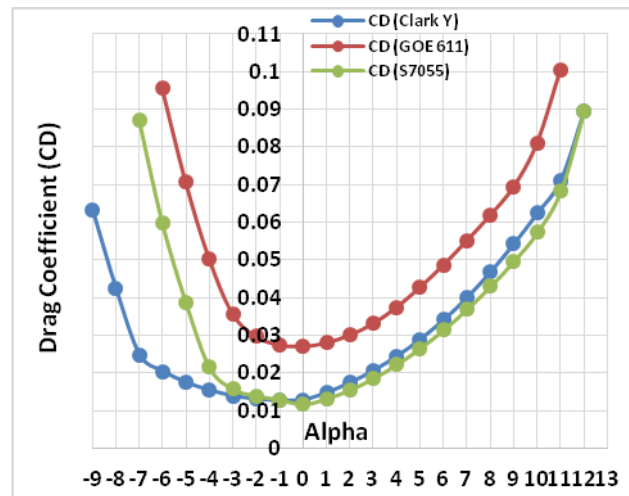
Figure 10. Drag coefficient vs. alpha at speed 20 m/s

Then for the air drag coefficient produced by Clark Y, Goe 611 and S7055 airfoils at 0-degree angles of attack are 0.0128, 0.027 and 0.0116 respectively. From Figure 10 seen in all angles of attack, the trends of drag coefficient at cruise speeds (20 m/s) are smaller than at takeoff speeds (12 m/s).
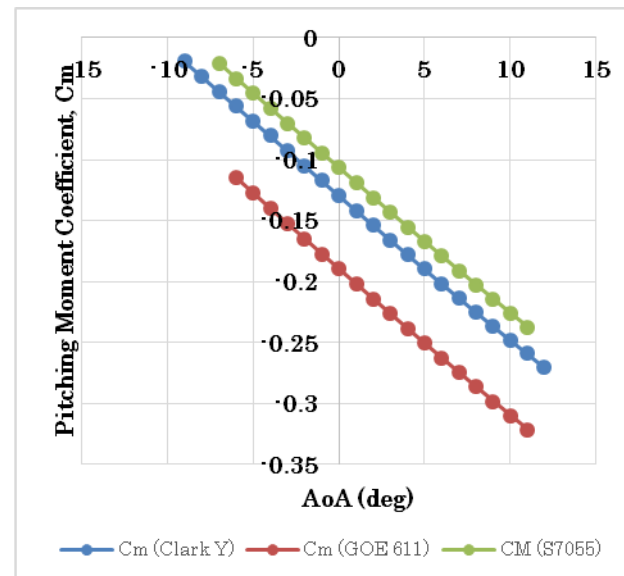

Figure 11. Pitching moment of the coefficient (Cm) vs. AoA at speed 20 m/s

Furthermore, as shown in Fig. 11, the simulation results of the pitching moment coefficients of the three types of airfoils at cruise speeds (20 m/s) have the same trend as the simulation result at the take-off speed (12 m / s). It saw that graph of pitching moment coefficients at all angles of attack having a negative gradient. This trend indicates that the good stability of the longitudinal wings of the UAV Serindit V-1 at all angle of attack conditions.
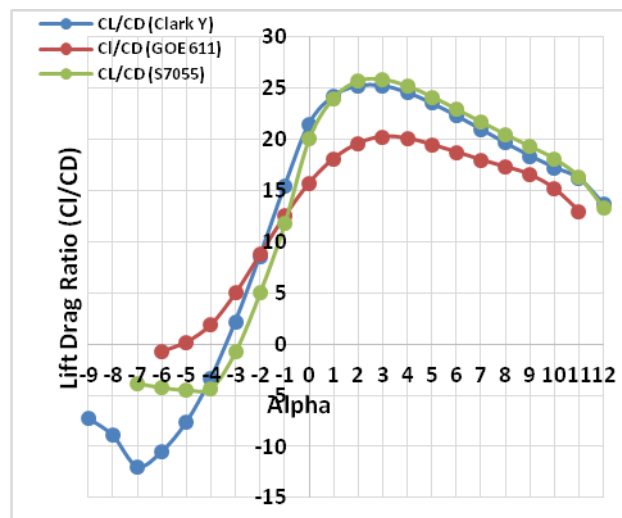
Figure 12. Lift drag coefficient ratio (Cl/Cd) vs. alpha at speed 20 m/s

Figure 12 shows the simulation results of the lift-drag coefficients ratio (Glide ratio) at cruise speed (20 m / s). In the graph, see the largest glide ratio at a 0-degree angle of attack is generated by the Clark Y airfoil, followed by the S7055 airfoil and GOE 611 airfoil. However, overall, the largest glide ratio occurs at a 3-degree angle of attack where the value of the glide ratio of S7055 airfoil, Clark Y and Goe 611 airfoil are 25. 803, 25.206 and 20.245 respectively. The largest glide ratio value at cruise speed is an important consideration in choosing the type of wing airfoil that requires high endurance flight.

4.4 Wing simulation result of UAV Serindit V-1 at maximum speed (30 m/s)
The result of simulation of UAV Serindit V-1 wing at maximum speed (30 m/s) shown the drag coefficient produced by Clark Y, Goe 611 and S7055 airfoil at 0-degree angle of attack are 0.0113, 0.0251 and 0.0102 respectively. From Figure 13 seen at all angles of attack, the trend of drag coefficient generated at maximum speed (30 m/s) is smaller than at the cruise speed.
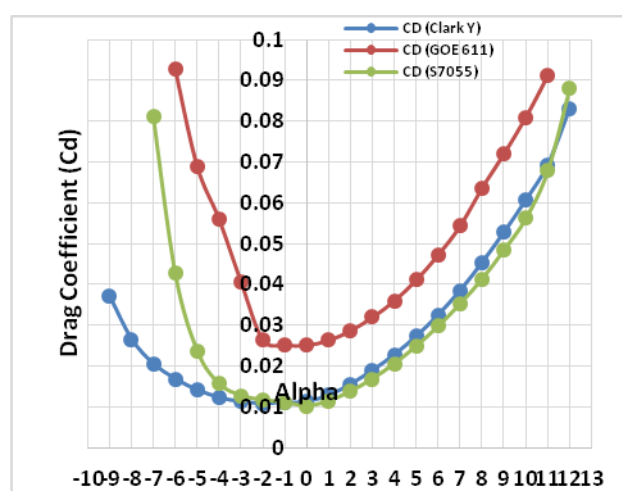

Figure 13. Drag coefficient vs. alpha at speed 30 m/s

The simulation results of the lift drag coefficient (Glide ratio) at maximum speed (30 m /s) shown in figure 14. In the graph show that the highest lift drag coefficient ratio at a 0-degree angle of attack is produced by Clark Y airfoil, followed by S7055 and GOE 611 airfoil. However, overall, the largest

glide ratio value occurs at a 2-degree angle of attacks where the S7055, Clark Y and Goe 611 glide ratio values are 28.81, 28.13 and 20.51, respectively.
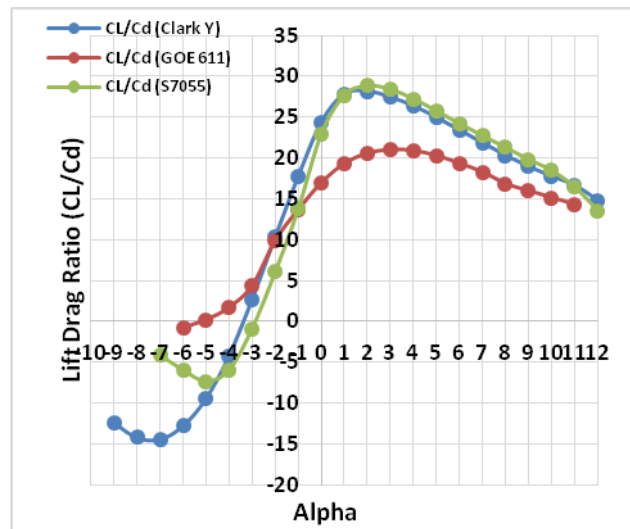

Figure 14. Lift drag coefficient ratio (Cl/Cd) vs. alpha at speed 30 m/s.

5. Conclusion

In this research, the initial geometry of the wing UAV serindit V-1 was determined using the basic method of aircraft design. Furthermore, the wing UAV Serindit V-1 is simulated on XFLR5 software to see its aerodynamic characteristics at take-off speed, cruise speed, and maximum speed. The simulation of the wing UAV Serindit V-1 was performed on the airfoils of Clark Y, GOE 611 and S7055. The following explains the conclusions of this research:

1. The lift coefficient produced by the three airfoils at the at take-off speed and at the cruise speed meets the requirements because the lift coefficient value exceeds the minimum lift coefficient required.

2. The highest value of the lift drag coefficient ratio at cruise speed, produced by S7055 airfoil at a 3-degree angle of attack.

3. The pitching moment coefficient at all angles of attack produced by the three airfoils is having a negative gradient. This shows the condition of wing stability in the pitching direction is a meet requirement.

References

[1] Austin, Reg. 2010. Unmanned Aircraft System. USA: John Wiley & Sons, Inc.

[2] Fahlstrom, paul. 2012. Introduction to UAV system. USA: John Wiley & Sons, Inc.

[3] Badan Pusat Statistik Provinsi Riau. 2015. Luas Areal Perkebunan Menurut Jenis Tanaman 2011 - 2015 (Ha). From https://riau.bps.go.id/linkTabelStatis/view/id/310.

[4] Rakesh and Sunil. 2015. Design of solar powered RC Aircraft. The international journal of engineering and science (IJES)

[5] Basaran, Bilek. 2015. Unmanned Aerial Vehicle Design And Production. Turkey. Ankara International Aerospace Conference (AIAC).

[6] Lennon, Andy. 2005. Model Aircraft Design. USA: Air Age Me.

[7] MIT. 2006. Basic Aircraft design Rule. The USA. MIT OPEN COURSEWARE

[8] Driessen F, Leussen M., Senders A., Vliet T., Vlugt S. (2013), *An autonomous quadcopter with environment mapper*, Huginn, Eindhoven University of Technology

[9] UIUC Applied Aerodynamic Group. 2017. UIUC Airfoil Coordinates Database. from http://m-selig.ae.illinois.edu/ads/coord_database.html

[10] Selig, Broeren and Guiglielmo. 1995 Low-Speed Airfoil test. University Of Illinois News Bureau. Soartech publication.