Flight Test of GL-1 Glider Half Scale Prototype

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Abstract. GL-1 is a single-seat mid-performance glider, designed to be Indonesian National Glider. The Glider have been developing since 2014. The development produced a half scale prototype called BL-1, which had accomplished static test in 2016, then followed by first flight test at April 20\textsuperscript{th} 2017, and second flight test at May 21\textsuperscript{st} 2017. The purpose of the flight test was to obtain familiarization of the aircraft, aerodynamics characteristics and flow visualization, with data from flight recorded in FDR. The flight test resulted in two flights with total length of 21 minutes. The data from FDR and flight test documents extracted to analyze the characteristics and behavior of the aircraft during flight test. The aerodynamics characteristic was close to analytical results. The control was good; however, the effectiveness of control surface may need to be further analyzed. The result of the flight test will be used as a reference for further improvements and may need further testing.

Keyword: Flight Data, Flight Test, Glider, Sub-scale Prototype

Nomenclature
\begin{tabular}{ll}
\text{\textbf{\text{\textbf{\rho}}}} & \text{Air Density in kg/m}^3 \\
\text{\textbf{\text{\text{ASL}}}} & \text{Above Sea Level} \\
\text{\textbf{\text{\text{CFD}}}} & \text{Computational Fluid Dynamics} \\
\text{\textbf{\text{\text{CL}}}} & \text{Coefficient of Lift} \\
\text{\textbf{\text{\text{FDR}}}} & \text{Flight Data Recorder} \\
\text{\textbf{\text{\text{HTP}}}} & \text{Horizontal Tailplane} \\
\text{\textbf{\text{\text{ISA}}}} & \text{International Standard Atmosphere} \\
\text{\textbf{\text{\text{m\text{\text{aircraft}}}}}} & \text{Weight of aircraft in kg} \\
\text{\textbf{\text{\text{MAC}}}} & \text{Mean Aerodynamic Chord} \\
\text{\textbf{\text{\text{V}}}} & \text{Airspeed at flight} \\
\text{\textbf{\text{\text{VTP}}}} & \text{Vertical Tailplane} \\
\text{\textbf{\text{\text{RoC}}}} & \text{Rate of Climb} \\
\text{\textbf{\text{\text{t}}}} & \text{FDR time in minute} \\
\text{\textbf{\text{\text{W/S}}}} & \text{Wing loading} \\
\end{tabular}
1. Introduction

GL-1 is a single-seat mid-performance glider, designed to be a national glider to replace the aging fleet of gliders in Indonesia. The development of GL-1 is in collaboration with an aircraft workshop in Pondok Cabe, South Tangerang. The first design of GL-1 had been proposed by Sulc [1] and Pratama [2]. Estimation of GL-1 aerodynamic characteristics and performances had been explored by using analytical method [2], drag polar method based on flight manual data [3][4], CFD simulation [5], and X-Plane simulation [6]. Distribution of aerodynamics forces over GL-1 wings using CFD had also been studied by Amalinadi [7].

A half scale prototype called BL-1 was built in 2016, based on the design by Pratama [2]. It was displayed on Indonesian National Glider Workshop that was held during glider branch of Pekan Olahraga Nasional (PON) 2016, in Subang. BL-1 had conducted a wing static test in 2016 and first flight test at 20th of April 2017. As a result of first flight test, BL-1 had been modified with an addition of outrigger in each wing, a nose landing gear, and an increased surface of rudder and elevator. The incidence angle of HTP had also been fixed. The modification was intended to help the aircraft during takeoff. However, these improvements demand more flight test to prove the improved design. The purpose of the next flight test was to obtain familiarization of the flying characteristics, and to check control effectiveness and aerodynamic characteristics of the aircraft.

2. BL-1 Specifications

GL-1 half scale prototype (named BL-1) was the test aircraft. The aircraft was controlled using remote control. BL-1 was equipped with detachable 2-piston gas engine with two-blade propeller to be able to conduct both motored and towed flight. A flight controller was installed in BL-1 to store flight test data. The function of the flight controller was to log data (FDR) and send signals to actuator. The data will be recorded directly to the SD card and will be processed after the plane has landed. While the flight controller can only handle low current of servomotor, power supplied to the servomotor will be separated. Though it is capable to fly in several flight modes, only manual mode used in this test to ensure pilot’s input will be directly send to the servomotor. Table 1 shows the summary of BL-1 technical data.

| Wing Span   | 7.15 m |
|-------------|--------|
| Wing Area   | 3 m²   |
| Wing Aspect Ratio | 17      |
| MAC         | 0.43 m |
| MAC location | 2.5 cm from Wing Root LE |
| Wing Incidence | 3 deg  |
| Wing Twist  | -3 deg |
| Airfoil Wing| FX 62-K-153 |
| Engine Power| 10 HP  |
| Propeller Dimension | 27x10 inch |
| VTP Span    | 0.64 m |
| VTP Area    | 0.238 m² |
| VTP Aspect Ratio | 1.72 |
| Rudder Area | 0.083 m² |
| Airfoil VTP | FX 71-L-150/25 |
| HTP Span    | 1.3 m  |
| HTP Area    | 0.390 m² |
| HTP Aspect Ratio | 4.33 |
| Elevator Area | 0.135 m² |
| Airfoil HTP | FX 71-L-150/25 |

The Figure 1 below shows the schematics of BL-1 for the second flight test. The centerline defined as reference line for x-axis of the fuselage. The nose and main landing gear were a fixed landing gear, and the tail had a skid. Outrigger was added to each wing tip. The system was located under the canopy area. Engine and propeller placed above the fuselage, with engine boom located at 50% of wing root chord. Nose landing gear and outrigger was intended to help maintain attitude during takeoff. A panel with 60 mm width added to rudder and a panel with 50 mm width added to elevator. VTP and HTP area increased to improve control effectiveness during takeoff.
3. Flight Test Plan
The flight test was located in an airfield in Batujajar, Bandung, at Sunday, 21st of May 2017. The flight test was planned to be conducted in three phases, familiarization with motor, aerodynamics test with towed takeoff (engine off), and flow visualization. The purpose of the flight test was to get familiarization on the flying characteristics, test control effectiveness of the aircraft, and obtain the aerodynamics and stability characteristics of the aircraft [8].

4. Preparation
The preparation was located in two separate place, Pondok Cabe and Batujajar. The preparation in Pondok Cabe was preparation of the airframe and system before the test. At Batujajar, the aircraft would be prepared as follow: geometry measurement and conformity test, system preparation, weight and balance, and engine test [8].

4.1 Preparation in Pondok Cabe
Preparation in Pondok Cabe including the installation nose landing gear, wing outrigger, and the addition of rudder and elevator surface area to increase VTP and HTP surface area. All the control surface was checked and ready, while the flap was fixed because trouble in flap actuators. After that, the aircraft was brought to Batujajar disassembled into four components: fuselage, left wing, right wing, and HTP.

4.2 Assembly
The aircraft was assembled at Batujajar from four components: fuselage, left wing, right wing, and HTP. Because of this, conformity check was needed for the aircraft to be as close to the design as possible.

4.3 Pre-flight Preparation
The airframe and system of the aircraft was checked without any significant trouble.

4.4 Conformity Check
The aircraft needed to be as close to design as possible as confirmation that we could use the test result as an evaluation. The aircraft was checked for the alignment of the components, the incidence of wing and HTP, and the deflection of the control surface.
The alignment of the aircraft was checked by measuring the distance between the wing tip-HTP tip and wing tip-VTP tip as shown in Figure 2. The alignment check result was deemed acceptable. The incidence of the wing and HTP was checked at Pondok Cabe. Control surface deflection was also checked. The result is shown in Table 2.

| Deflections (degrees) | Signal  |
|-----------------------|---------|
| Aileron               | +25/-10 | 1719/1339 |
| Rudder (on Pondok Cabe)| +20/-20 | 1830/1311 |
| Elevator              | +15/-20 | 1943/1110 |

### 4.5 Weight and Balance

Weight and balance was important to ensure that the aircraft could fly stable and controllable. The plane weight and balance was measured using three weigh platform located on nose landing gear, left outrigger, and rear skid. The weigh and balance of the aircraft was calculated using the sum of the resultant weight and the sum of moment. Weight and balance was shown on Table 3.

| Weight | C.G. Location (mac) |
|--------|----------------------|
| 54 kg  | 15.5 cm from L.E. mac or 37% MAC |

### 4.6 Engine Check

Engine was checked and ready without any significant trouble.

### 5. Flight Test Execution

During flight test, the aircraft was able to flew twice in engine configuration, with a total of 21 minutes flight time. Milestones recorded and wind speed data measured using anemometer are shown on Table 4 and Table 5 consecutively. The second flight trajectory can be shown in Figure 3.

#### Table 4. Milestones during flight test

| First Flight | Time GMT+7 | Second Flight |
|--------------|------------|---------------|
| Event        |            | Event         | Time GMT+7   |
| Flight Prep  | 12:58      | Engine Start  | 15.27        |
First Flight

| Event   | Time GMT+7 |
|---------|------------|
| Engine Start | 13.18 – 13.20 |
| Takeoff  | 13.22      |
| Flypass  | 13.32      |
| Landing  | 13.34      |

Second Flight

| Event   | Time GMT+7 |
|---------|------------|
| Takeoff | 15.31      |
| Throttle 50% | 15.32 |
| Handoff | 15.34      |
| Flypass 1| 15.38      |
| Flypass 2| 15.39      |
| Landing  | 15.40      |

Table 5. Wind speed recorded

| Windspeed | Direction | Time GMT+7 |
|-----------|-----------|------------|
| First Flight |          |            |
| 3.3 m/s    | Northwest | 13.17      |
| 2.4 m/s    | Northwest | 13.22      |
| 2.4 m/s    | Northwest | 13.27      |
| 1.5 m/s    | Northwest | 13.32      |
| 2.1 m/s    | Northwest | 13.35      |
| Second Flight |        |            |
| 0.8 m/s    | Northwest | 15.25      |
| 1.6 m/s    | West      | 15.31      |
| 3.2 m/s    | West      | 15.33      |
| 2.3 m/s    | Northwest | 15.35      |
| 2.0 m/s    | Northwest | 15.38      |
| 0.6 m/s    | Northwest | 15.40      |

Figure 3. Flight trajectory of the second flight.

5.1 First Flight

The first flight was intended for familiarization using engine. The flight took 12 minutes from takeoff to landing. The aircraft had no trouble during takeoff and cruise. During takeoff run, one of the wing outrigger and nose landing gear supported the aircraft. The pilot also said that the control of the aircraft was good. However, the pilot felt that the pitching of the aircraft was too sensitive.

There were several problems during landing for the first flight. The engine was shut down. The rudder effectiveness was considerably decreased. This resulted in a hard landing with quick repairable damage.

Examination after landing had shown that the data of first flight was lost. The low saving rate of micro SD had caused the data lost; thus, all of the data had corrupted. The lost data demanded for a second flight.

For the second flight, the pilot was told to be more careful during landing, and conducting longer approach so the behavior of the aircraft during landing could be observed more. The SD card of the FDR was replaced to ensure the data was saved.
5.2 Second Flight

The second motorized flight was 8 minutes long. Overall performance was almost the same as first flight, with the pitching moment was still too sensitive. Even though the aircraft was maintaining longer approach and considerable thrust, sensitive pitching moment combined with decreased rudder effectiveness resulted in a significant damage during landing. The prototype was unable to continue for towed test and flow visualization test. Fortunately, FDR data was save.

6. Data Processing

As discussed in 5.1 and 5.2, the data from first flight was lost because of a problem in the SD card. Therefore, the data processed are from second flight only. Minute 0 is the time when the FDR is switched on. Data used for analysis is shown on Table 6.

| Name                      | Notes                                           | Data Rate |
|---------------------------|-------------------------------------------------|-----------|
| Time                      | Time obtained in microseconds, converted to seconds and minutes | Varied    |
| Attitude (pitch, roll, yaw) | Obtained from Magnetometer                     | 1477 Hz   |
| Airspeed                  | Pitot data error, obtained by subtracting groundspeed with windspeed | 295 Hz    |
| Groundspeed               | Obtained from GPS                               | 295 Hz    |
| Vertical Speed            | Obtained from GPS and calculated from rate of altitude change over time | 295 Hz    |
| Altitude                  | Obtained from GPS                               | 295 Hz    |
| Height                    | Calculated by altitude - altitude at 0 minutes (ground,) | 295 Hz    |
| Gamma                     | Calculated by finding the angle between horizontal speed (airspeed) and vertical speed | 295 Hz    |
| Alpha                     | Calculated by subtracting pitch angle with gamma angle | No data rate |
| Elevator, Aileron, Rudder Signal | Obtained from FDR                        | 591 Hz    |
| Throttle Signal           | Obtained from FDR                              | 591 Hz    |

6.1 Major Flight Milestones

Below are tables of flight test milestones from flight test report. The time from flight test report is compared to the data obtained from FDR. The data is shown between 8 to 18 minutes. The time in the relation of times in flight-test report (GMT+7) and from the FDR is shown on Table 7.

| Event          | Time GMT+7 | Time FDR       |
|----------------|------------|----------------|
| Engine Start   | 15:27      | -              |
| Takeoff        | 15:31      | Minutes 8.2 - 8.4 |
| Throttle 50%   | 15:32      | Minutes 8.7    |
| Handoff        | 15:34      | Minutes 10.7   |
| Flypass 1      | 15:38      | Minutes 14.9 - 15.3 |
| Flypass 2      | 15:39      | Minutes 16.2 - 16.5 |
| Landing        | 15:40      | Minutes 17.2 - 17.5 |

6.2 Takeoff

The behavior and performance of the aircraft during takeoff will be analyzed in this section. The behavior analyzed including the attitude and the effect of addition of the outrigger and nose landing
gear. The performance analyzed is the aircraft takeoff run, lift off speed, lift off distance, and lift off angle.

This paragraph will analyze the behavior of BL-1 during takeoff according to Figure 4 to Figure 7. At the start of the takeoff, aircraft is at an attitude with its main landing gear, rear skid, and wing tip gear in ground (5 degrees of pitch angles, circled in red in Figure 5). After the engine started at 8.15 minute, with increasing throttle, the aircraft started to move at 8.2 minutes. After obtaining airspeed of 5 m/s at 8.26 minutes, the aircraft started to pitch down until the nose gear near the ground (pitch angle of -20° to 0°, circled in red in Figure 5) at 8.33 minutes and speed of 15 m/s, this happen without any correction from the pilot (no elevator deflection detected). This condition was maintained until 8.37 minutes with averaged angle of attack of -1°. The pilot started to deflect the elevator up at 8.345 minutes. After 3 seconds from the nose touch the ground, the nose started pitching up, and at 8.4 minutes, the aircraft started to lift off at 5° of pitch and 20° of angle of attack (circled in Figure 4 and Figure 6). During takeoff, to adjust the heading of aircraft, the pilot used only rudder.

![Figure 4. Altitude data during takeoff](image)

![Figure 5. Pitch and gamma during takeoff](image)

![Figure 6. Airspeed data during takeoff](image)

![Figure 7. Control signal data during takeoff](image)
Table 8. BL-1 Takeoff Characteristics

| Name                     | Notes                                      |
|--------------------------|--------------------------------------------|
| Liftoff distance         | 114 meters Ave takeoff speed of 9.5 m/s, for 0.2 minutes. |
| Lift off airspeed        | 20 m/s Height 1.88 m, 8.4 minutes.         |
| Lift off angle of attack | 2° Height 1.88 m, 8.4 minutes              |
| Takeoff distance         | 2.0 meters 15 feet, at 8.45 minutes         |

6.3 Climbing

The behavior and performance of the aircraft during climbing will be analyzed in this section. The performances analyzed including climb rate, climb speed, and climb angle.

According to FDR data, the aircraft started climbing at 8.4 minutes, with average vertical speed of 2.5 m/s and maximum climb rate of 4.2 m/s, until reaching heights of 180 meters at minutes 10.0. The aircraft was climbing with a throttle of 90% at first, and after 9 seconds, the throttle was decreased to 50% for the reminder of the climb. The climb took 1.6 minutes to occur. The data from FDR shown that the aircraft only have roughly 30 seconds total of straight climbing (at 8.7-8.8 and 9.3-9.7 minutes), while the other climb occurred while banking/turning. Table 9 provided the summary climb characteristics obtained from FDR data.

Table 9. BL-1 Climbing Characteristics

| Name                | Notes                                      |
|---------------------|--------------------------------------------|
| Max RoC             | 4.2 m/s 90% Throttle, while banking 20-30 degrees at 8.5-8.65 minutes. |
| RoC                 | 2.5 m/s 50% Throttle, averaged at 8.7-8.8 and 9.3-9.7 minutes. |
| Climb Angle of Attack | 0°                                    |
| Climb Angle         | 6°                                        |
| Climb Speed         | 17.8 m/s                                   |

6.4 Cruising

The behavior and performance of the aircraft during cruising analyzed in this section. The performance analyzed is the aircraft cruise speed and cruise angle. Also will be determined the trim used during cruise.

From the FDR data, the aircraft’s straight level cruise occurred at 10.1-10.3 minutes, 11.7-11.8 minutes, and 13.0-13.3 minutes. The aircraft performed two fly passes at 14.9-15.2 and 16.20-16.5 minutes. Also, from Table 7, at 15.34 GMT+7 or 10.7-10.9 minutes, the pilot was performing a trimmed and handoff flight for 12 seconds. Throttle used are 50% during cruise at 10.1-10.3 and 11.7-11.8 minutes, 40% during cruise at 13.0-13.3 minutes, and 30% during fly passes. Handoff flight occurred at 10.7-10.9 minutes. Average speed of 18 m/s, alpha -0.5°, at 180 m. Noted that during handoff flight, while there is no roll, the aircraft are slowly turning from heading 300 to 330. Table 10 provide the summary of cruise characteristics obtained from FDR data. The trim settings of the aircraft obtained from the remote control was shown in Table 11.
### Table 10. BL-1 Cruise Characteristic

| Name                  | Notes                                      |
|-----------------------|--------------------------------------------|
| Cruise Speed (50%)    | 23.4 m/s                                   |
| Ave Alpha (50%)       | -0.7°                                      |
| Altitude              | 180 m                                      |
| Cruise Speed (40%)    | 19.7 m/s                                   |
| Ave Alpha (40%)       | -0.5°                                      |
| Altitude              | 140 m                                      |
| Cruise Speed (30%)    | 20 m/s                                     |
| Ave Alpha (30%)       | -0.5°                                      |
| Altitude              | 18 m                                       |

### Table 11. BL-1 Trim Data

| Trim  | Trim | Signal | Deflection |
|-------|------|--------|------------|
| Aileron | 32 % | 1556   | 10°         |
| Elevator | 56 % | 1529   | -2°         |
| Rudder  | 8 %  | 1507   | -4°         |
| Throttle| 50 % | 1520   | -           |

### 6.5 Landing

The behavior and performance of the aircraft during landing will be analyzed in this section using data from FDR and video recorded during landing. The behavior analyzed including the attitude of the aircraft during landing. The cause of hard landing will also be analyzed.

This paragraph will analyze the behavior of BL-1 during landing according to Figure 8 to Figure 11.

The aircraft started preparing for landing after the second fly pass, turning 360 degrees before flying parallel to the runway at 17.15 minutes, at a height of 17 meters above the runway. During approach, the pilot reset the trim of the aircraft to compensate moment induced by decreasing throttle. Once the aircraft is parallel to the runway, the throttle was decreased from 30% to 20%. The pilot was not able to trim the aircraft, indicated by fluctuating pitch angle and elevator deflection in FDR readings. At 17.35 minutes, the aircraft had experienced a rather high angle of attack at 12 degrees, and low speed at only 15 m/s, at a height of only 7 meters from the ground. Maybe, detecting this, the pilot decided to increase the throttle to 100% to nose down the aircraft, while instantly counter by deflecting the elevator down.

At this point, the pilot was trimming the aircraft using both engine throttle and elevator deflection. At 17.38 minutes, the aircraft experienced one high angle of attack again at 12 degrees, low speed at only 16 m/s, at an height of only 4.5 meters from the ground. At 17.40, detecting that the aircraft is pitching down again, the pilot lowered the throttle to 0% and then at 17.42 increasing the throttle to 50% as he sensed the aircraft to pitch up again, while deflecting the elevator up to counter it. At this point, the aircraft have height at 2 meters above the ground, at the speed of 16.8 m/s. At 17.43, the pilot increased the throttle to 100% and deflecting the elevator at maximum negatives, because the aircraft was pitching too down. This is not helping though as in 17.44, the aircraft pitching up very abruptly. After 17.45 minutes, weird things happened. The aircraft started the change heading 180 degrees, experiencing an alpha of maximum 12 degrees at 17.452, at 17.46 the pilot started the deflect the rudder left to counter the spin with no avail, touch the ground at 17.48, and then stopped spinning and moving at 17.5.
6.6 Aerodynamics Characteristics
The aerodynamics characteristics of the aircraft are calculated only at straight and level condition, thus at condition where roll is zero, the heading is constant, with constant speed and altitude. However, the condition was not easily obtainable. Therefore, any condition that acceptable to represent straight and level condition will be used for analysis, as seen in Figure 12. Also, the thrust is assumed to be negligible. As consequences, only the lift characteristics could be analyzed.
According to Appendix in reference [9], coefficient of lift obtained from the equation:

$$C_L = \frac{W/S}{\frac{1}{2} \times V^2 \times \rho}$$

The density of air is assumed to be equal to density at 800 m ASL ISA+15 ($\rho = 1.07 \text{ kg/m}^3$)

The mass of aircraft is decrease during flight due to fuel consumption. However, because there is no data on fuel consumption, the 3 liters of fuel is assumed to be constantly decreasing on the 20 minutes flight until empty. Fuel density assumed 0.8 kg/liters. At the start of the second flight, the fuel is assumed to be used 12 minutes or equal to 1.4 kg, so the weight of the aircraft at the second flight was 52.6 kg. With the rate of 1kg/minutes, the weight of the aircraft during the second flight is calculated as follows:

$$m_{aircraft}(t) = (52.6 - 1 \times (t - 8)/10) \text{ kg}$$

However, the characteristics are averaged from several data to minimize outlier results, as shown in Table 12.

**Table 12. Example of averaged result**

| Time [minute] | Airspeed [m/s] | $\alpha$ [°] | CL [-] | Time [minute] | Airspeed [m/s] | $\alpha$ [°] | CL [-] |
|--------------|----------------|-------------|-------|--------------|----------------|-------------|-------|
| 10,165       | 23.89          | 0           | 0.56656 | 17,34        | 16.09          | 11          | 1.23191 |
| 10,185       | 23.3           | -5          | 0.5956 | 17,345       | 15.83          | 13          | 0.95452 |
| 10,195       | 23.55          | -2          | 0.58301 | 17,35        | 15.07          | 15          | 0.84257 |
| 10,205       | 23.82          | 3           | 0.56985 | 17,355       | 13.83          | 7           | 0.83369 |
| 10,21        | 23.12          | 3           | 0.60488 | 17,36        | 13.19          | 0           | 1.83309 |
| **Average**  | 23.536         | -0.2        | 0.58398 | **Average**  | 14.802         | 9.2         | 1.13915 |

Figure 13 shows comparison of aerodynamics characteristics obtained from BL-1 flight test, GL-1 DATCOM simulation [2], GL-1 CFD simulation [5], and GL-1 X-Plane simulation [6]. It could be seen that BL-1 lift vs slope coefficients follow the trend as resulted from simulations.
Figure 13. Aerodynamics characteristics of BL-1 obtained in test compared to several methods

7. Conclusion

7.1 Control Effectiveness

As seen in chapter 6, the control effectiveness of BL-1 had mixed results. Based on both FDR data and flight test report, BL-1 was trimmable at 30-50% throttle. However, at 20% and lower throttle, the pilot was unable to find the longitudinal trim. The pilot also stated that during the flight, the elevator deflection was being too sensitive. The aileron was capable of rolling/banking the aircraft throughout the flight, even at very low speed as displayed in figure to figure. The rudder effectiveness may need improvement. At the second takeoff, the FDR data show that rudder could control the aircraft at a low speed of 6 m/s. However, at landing, the rudder was not able to control the aircraft below 16-17 m/s. This could happen because when the rudder was used, the throttle while takeoff was higher than while landing. Higher throttle means that at takeoff, the rudder might have larger induced velocity. In addition, at takeoff, the rudder was deflected much larger than while landing. Those two factors may lead to higher effectiveness of the rudder while takeoff compared to when the aircraft was landing. Also, as it is a scaled down prototype, it may needed a higher velocity for the airfoil to be effective compared to the full-scale counterpart.

7.2 Aerodynamics Characteristics

The lift coefficient calculated from FDR data are very close to the estimation from several methods before, while the closest one being from X-Plane simulations. The aircraft had detected angle of attack as high as 12 degrees, while not stalling. However it seems like the aircraft had too large engine power, resulting in the rate of increase in pitch down moment induced by the engine are too large.

The thrust of the propulsion might have an effect on the aerodynamics characteristics, especially because it had large propulsion. It might lead to better calculation of the aircraft aerodynamics characteristics.

7.3 Design and Future Works

As the result of the second flight test, the design of GL-1 empennage may need to be reconsidered. The prototype may need to be tested without engine, to obtain aircraft characteristics closer to the full scale.
However, the behavior of half-scale and full-scale prototype may differ; thus, the full design may need to be further tested by flight simulations and full-scale prototype.

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