Preliminary Design of GL-1 Sailplane Cockpit Arrangement and Control Mechanism Based on EASA CS-22 Requirements

T Mulyanto1,*, M F Zulkarnain1
1 Faculty of Mechanical and Aerospace Engineering, Institut Teknologi Bandung, Jl. Ganesha No. 10, Bandung, Indonesia.
*Email: taufig.mulyanto@ae.itb.ac.id

Abstract. Sailplaning or gliding is one branch of aero sports activities in Indonesia under Federation of Aero Sport Indonesia (FASI). Until now, the most common sailplane used in Indonesia is still Schweitzer SGS 1-26, which is a single seated metal-fabric sailplane designed in 1955 and produced until 1979. The development of a new national glider to replace the Schweitzer SGS 1-26 had been conducted since 2013 and resulted in a design named GL-1. The EASA CS-22 had been chosen as certification basis for GL-1 as there is no equivalent yet in Indonesian CASR. A preliminary design of internal cockpit arrangement and control mechanism has been conducted. This study shows that the control mechanism using a combination of cable and push-pull rod arrangement satisfy the required control surface movement and limited sailplane interior space.

Keyword: Sailplane, Preliminary Design, Certification, Cockpit, Control Mechanism.

1. Introduction
Preliminary study on mid-performance glider were conducted since 2013 with some configuration study [1] and performance estimation [2] as a study final report. However, GL-1 was first designed by Pratama [3]. 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]. Amalinadi [7] had also studied distribution of aerodynamics forces over GL-1 wings using CFD. A half scale prototype called BL-1 based on the design by Pratama was built in 2016. It was displayed on Indonesian National Glider Workshop that was held during biannual National Sport Event. BL-1 had conducted a wing static test in 2016 and flight test at April 2017 and May 2017 [8]. Structural design and analysis had been conducted by Darsono [9]. The full scale prototype is in production and is targeted to have its first flight in 2019.

To continue the development and achieve 2019 flight test, design of the internal configuration, especially in cockpit and control mechanism, will be needed. This paper will explain cockpit and control mechanism design process and results. European EASA CS-22 is used as basis requirements as there is no equivalent regulation in Indonesia. The study will be focused on the configuration and arrangement of seating, cockpit control, instrument panel, and control mechanism. For control mechanism, only elevator, aileron, and rudder will be discussed. Other related to cockpit design such as stick force, structural integrity, emergency condition, etc will be discussed separately.

2. GL-1 Design and Specifications
GL-1 is a single seater mid performance sailplane. Its low rate of sink with moderate aspect ratio is designed for Indonesian small and weak thermal condition. GL-1 is also designed with low stall speed so the aircraft could be towed by microlight or ultralight, which is more common in Indonesia.
compared to tow aircraft and winch launcher. Aircraft specification and dimension can be seen in Table 1 and Fig. 1.

| **Table 1. Summary of GL-1 technical data** |
|-----------------|-----------|
| Wing Span       | 14.3 m    |
| Wing Area       | 12 m²     |
| Wing Aspect Ratio| 17        |
| Fuselage Length | 6.8 m     |
| Empty Weight    | 190 kg    |
| MTOW            | 300 kg    |
| Best L/D        | 30        |
| Minimum R/D     | 0.76 m/s  |
| Stall Speed     | 14.8 m/s  |
| Elevator Deflection | 25° up and 30° down |
| Aileron Deflection | 30° up and 10° down |
| Rudder          | 25° right and left |
| Flap            | 25° down  |

3. Certification Study
EASA CS-22 is certification specific for sailplane and motorized sailplane [10]. The structure of CS-22 is actually very similar to CASR 23 [11], with special consideration for sailplane design such as towing, water ballast, etc.

For this design, specific regulation for mechanism and cockpit will need to be collected. There are total of 32 regulation for mechanism and cockpit. Most of arrangement, design features, and operation are discussed primarily in Subpart D of CS-22. Handling quality and performance are discussed in Subpart B and D. While equipment lists are regulated in Subpart F. However, for the scope of this study, only requirements that related to configuration and arrangements are considered for preliminary design.

3.1. Cockpit Requirements
CS 22.771 and .777 explained that the cockpit design and arrangements must be designed to able the pilot to control the aircraft accordingly. The pilot must be able to move the control freely without any interference from any objects in the cockpit. Arrangements and operation of the cockpit control must be designed to avoid confusion and inadvertent operation. CS 22.779 and CS 22.780 regulate the arrangement and operation of the main cockpit controls. However, the requirements for instrument panel is not as clear as in CASR-23, so a study on typical instrument arrangements on similar sailplane must be conducted.

3.2. Control Mechanism Requirements
As stated in CS 22.671 and CS 22.685, the operation and arrangement of control mechanism must be easy, smooth, and positive, avoiding confusion and inadvertent operation. As explained in 3.1, the operation of control mechanism is regulated on CS 22.779 and CS 22.780. The design must also conform to proper maximum control load and convenient stick force direction. Furthermore, the mechanism must be able to operate without interference from other mechanism or structural object. This was checked using analytic and kinematics simulation.
In this study, the aircraft is assumed as rigid body. However, it is not the case in reality. Usually, high performance gliders have a high deformation, and the study on the effect of those high deformation to control mechanism must be conducted separately.

4. Results

4.1 Cockpit Design

The cockpit of GL-1 is designed for Indonesian pilot with height between 1.6 meters to 1.85 meters [12]. The cockpit design geometry variable were pilot location, seat inclination, and knees location. For light sport cockpit [13], the pilot is usually located in the aft area of the cockpit due to wider cross section area. The inclination of backrest will usually be small and knees and leg require to be wide and provide comfortable seating position. However, due of the very narrow design of the GL-1 nose and cockpit area, a careful compromise will be needed. Narrowing front fuselage will make the pilot moved forward and have a considerable amount of back inclination. The leg area will also be cramped especially in the area of the rudder pedal.

After several iteration, the pilot is positioned 1.38 meters from nose with 40 degrees seat inclination. The location is designed so it will not be too cramped for the tallest pilot and the control is still reachable for shortest pilot. Figure 2 shows the pilot seating position.

![Figure 2. Pilot Location and Seating Configuration](image)

Besides CS-22 requirements, existing sailplanes type in Indonesia is also studied. A familiar cockpit arrangement would ease pilot transition to the new sailplane. Some arrangement highlights were made. Control stick is located in the middle between pilot feet. Airbrake and flap handles are located on the left-hand side of the cockpit so the right hand will always be on stick during flight. Tow release handle is located to the left side below the stick. Adjustable rudder pedal is installed to accommodate wide range of pilot height.

There is no clear guidance in CS-22 on arrangement of instruments panel. According to the CS 22.1303, the instruments needed for normal flight are Airspeed Indicator and Altimeter. However, existing glider usually adds more instruments such as Variometer and GPS. Thus, a study of more than 40 gliders from year 1970 to modern glider with varied role and performance was conducted to analyze the trend of instruments arrangements in glider. A list of instruments type will be listed and counted. For each type of instrument and each glider a tabulation of size and location were made. The GL-1 instrument type and arrangement were decided based on the statistic from the tabulation. A study on eye-instruments distance is also conducted from several existing gliders.
Other than airspeed and altimeter, variometer and magnetic compass are always installed in most glider. Another different type variometer sometimes added in the panel, so there will be two variometer. A radio/atc transceiver and a display/gps/computer is usually installed on more than 70% selected glider, especially on glider made after 1990. Attitude indicator instruments is rarely used, counted only 40%, however this is compensated as every glider usually has sideslip indicator in the canopy. Thus, all of the instruments listed which are frequently used will be installed in GL-1. A turn-bank indicator will also be installed as it is frequently used on other light aircraft.

Instrument panel is usually divided into several section horizontally and vertically: above instruments, upper left, upper center, upper right, far left, mid left, mid center, mid right, far right, bottom left, bottom center, bottom right, and below instrument panel. The arrangement of airspeed, altimeter, attitude indicator is usually very similar to CASR-23: airspeed left, attitude center, and altitude right. The radio/atc transceiver is always located on the bottom center part of the panel. Since there are usually two variometers, their location is usually separated and placed on the remaining empty space. Magnetic compass is usually located above the panel, on the right of panel, or outside the panel.

Instruments are usually come with the circular size of 3” and 2”. However, radio and LCD display have rectangular form. In modern glider, the use of large display for performance computer or GPS is on the rise. Due to the size of the display, the other instruments will need to be shrink in size. Instrument type which usually installed with 3” size in older gliders, are all installed in 2” size for modern glider with computer or GPS display. Even though the instruments are smaller, the eye-instruments distance is larger. The trend shows that modern gliders have distance of 600-750 mm compared to 550-750 mm in 1970s. Thus, the farthest distance will be used, but with a balance of 3” and 2” instruments for clear pilot view and minimize panel space as no large display will be installed. The large display for computer or gps can be replaced by adding 3” computer/gps instruments or by adding attachments for external gps using smartphone.

The instrument panel will be located 930 mm from nose to accommodate maximum eye distance of 750 mm. The panel will be designed so that enough instruments could be installed. There are also leg space so the movements of pilot’s leg will not be inhibited during normal operations and emergency.

As depicted in figure 3, there are 8 slots in the instrument panel with four 3” slots and four 2” slots. There are three slots in the upper part, four slots in the middle, and one slot in the bottom. A 3” Airspeed Indicator, a 2” Attitude Indicator, and 3” Altimeter will be located in the upper left, upper center, and middle right respectively. A 3” Vertical Speed Indicator or Variometer will be located in the upper right. There is three possible locations for magnetic compass, above the instrument panel, on the far right of the instrument panel, or on the cockpit wall. A 2” slot in the far left is provided for a Handheld/Mobile GPS adaptor. An extra Variometer, a Performance Computer, or a GPS could be installed in the 3” slot in middle left.

**Figure 3.** Cockpit Arrangements of GL-1: 1) Instrument Panel, 2) Flap, 3) Airbrake, 4) Tow Release, 5) Control Stick, 6) Rudder

Instruments Arrangements of GL-1: a) Air Speed Indicator, b) Turn/Bank Indicator, c) Vertical Speed Indicator, d) GPS Adaptor, e) VSI/Computer/GPS (optional), f) Altimeter, g) Magnetic Compass, h) Transceiver (optional)

4.2 Control Mechanism

As there is no reference for configuration of glider control mechanism, a study of 11 maintenance manual, one glider drawings, and light sport aircraft construction handbook was conducted [13]. The
construction of light or sport plane control mechanism usually use steel cable. This is reflected on 1950s glider Schweizer 1-26 [14], which is the main glider operated in Indonesia [15]. However, this is not the case on the more modern sailplane such as PW-5 [16], Arcus [17], or LAK-17 [18]. The more modern and high-performance sailplane used combination of push-pull, torque tube, and crank as the main components for control mechanism. Steel cable use is limited to rudder and tow release mechanism. This might be the case as mechanism using push pull rod will have positive and smoother control [13]. This in line with the requirements explained in 3.2. Thus, GL-1 will use this design.

A study on existing glider control mechanism configuration and arrangements was conducted and some features are used as the main reference for design. Other consideration is to minimize the complexity of the mechanism aiming to ease manufacture process and reduce cost. Configuration which fulfill requirements explained in 3.2 and maximizing the objectives was chosen as the final configuration. However, one cannot simply transfer an existing control mechanism to fit in other glider since there are difference in geometry and other constraints. The chosen basic control mechanism configuration will need to be designed so that the control is within reach of the pilot, while the full mechanism has no interference with pilot, structures, or other control mechanism. Control mechanism operation requirements in CS 22.779 and 22.780 must also be fulfilled. The control must have a tendency to return to its neutral position, thus requiring the stick force direction must be opposite of the control movements. In some cases, a combination of two basic control mechanism configuration and a considerable design adjustment were need.

Control column in the middle was chosen as it is more familiar with Indonesian Pilot. Movement transfer for elevator and aileron passed through the sides of the cockpit. Even though control passage through the middle of the fuselage could provide simpler design, it wasn’t possible since the space are very limited due of the existence of tow mechanism and landing gear. Figure 4 shows GL-1 control mechanism configuration and arrangements.

![Figure 4. Control Column. Aileron Differential (top left), Wing Mechanism (left), Fuselage Mechanism (middle), and Empennage Mechanism (right).](image)

Legend: 1) Rudder Pedal, 2) Adjustable Rudder Mechanism, 3) Rudder Cable, 4) Control Stick, 5) Aileron Fuselage, 6) Aileron Fuselage to Wing, 7) Aileron Differential, 8) Elevator Fuselage, 9) Elevator to Empennage, 10) Aileron Wing, 11) Aileron Horn, 12) Aileron Hinge, 13) Aileron, 14) Elevator Horn, 15) Elevator 16) Rudder Horn 17) Rudder

The elevator uses push pull rod mechanism. The movement transfer is designed so when the pilot pulls the stick, the elevator will be deflected upwards. A modified LAK-17 elevator mechanism [17] was chosen as basic configuration for it simple mechanism. The main modification is to replace middle crank so the rod end bearings terminal that was used will be replace with simpler and cheaper fork end terminal.
The aileron is a push pull rod mechanism. It is designed so when the stick is rotated to the right, the right aileron will be deflected upwards. There are three gliders with distinct aileron mechanism configuration: Schempp Hirth series [16], DG Series [18] and LS series [19]. However, since they all have a combined flap-aileron, a modified Schempp Hirth mechanism was chosen as basic configuration because it’s easier to convert into aileron-only mechanism. The design also incorporated a feature to enable different aileron deflection between right and left aileron.

The rudder has a steel cable mechanism. It was designed so that when right rudder is deflected forward, the rudder will be deflected to the right. The rudder pedal is actuated by leaning/rotating the pedal forward instead of pushing the rudder pedal forward. This is needed to implement an adjustable rudder mechanism.

5. Conclusion
The preliminary design of GL-1 cockpit and control mechanism had been conducted. From 32 articles in CS-22 related to control and cockpit design, only nine related to arrangements and configuration is considered. The study of more than 40 glider, 11 maintenance manual, two drawings, and a light sport construction handbook was conducted to design the configurations and arrangements that could fulfill all the requirements. Instrument panel has 8 slots, two of them could be used to accommodate Handheld GPS, Performance computer with LCD display. Control mechanism used a combined cable and push-pull rod arrangement which can satisfy the required control surface movement and limited sailplane interior space.

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