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Design of Flight Control System Mechanism for National Glider GL-1

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Abstract. This paper reports a design of flight control system mechanism which will be implemented in the national glider GL-1. The flight control system in the glider GL-1 includes the following control surfaces: elevator, ailerons, and rudder for primary flight control system as well as flaps and airbrakes for secondary one. In designing the components of flight control system, selections of type, material, and dimension of components are based on loads computation as well as benchmarking to some modern gliders. Mechanism and kinematics of flight control system are designed to comply with regulation as well as space availability. Fully-mechanical flight control system is selected for the aircraft since the aerodynamic forces acting on the glider are not excessive. The aircraft uses a centre-stick as manipulator for pilot to control longitudinal and lateral movements, which is linked to elevator and ailerons by push-pull rods with coupled mechanism. Meanwhile, for directional control, an adjustable pedal is used. The pedal is linked to the rudder by tension cables. Plain flaps and flat-plat panel airbrakes are selected as flap and airbrake types in this glider. The flaps and airbrakes are controlled by mechanical levers, which are linked by push-pull rods.

1. Introduction

Indonesia is developing its first national glider to improve aero sport activities in the country. The glider is a single seater mid-performance sailplane with 14.3 m wing span and 7 m length of fuselage. The glider name is GL-1 and it was initially designed by a student of the Faculty of Mechanical and Aerospace Engineering ITB [1]. Since then, several studies of the glider, which includes estimation of aerodynamic characteristics and performance, structural design and analysis, as well as flight simulation, have been performed [2-6].

A half-scale prototype of the glider was built and had conducted a wing static test in 2106. In 2017 the half-scale prototype performed flight test [7]. However, the half-scale prototype had no flight control mechanism inside and remotely operated as an unmanned air vehicle. The development of the glider GL-1 is currently going into the phase of manufacturing a full-scale prototype. As a manned airplane, the full-scale prototype of GL-1 has to be equipped with flight control system. Therefore, a design of flight control mechanism which will be installed in the glider is required.

2. Methodology

In designing flight control mechanism of GL-1 there are some considerations that must be paid attention, i.e. space availability of the airplane, regulations referred to, and DRO of the GL-1 (especially concerning deflection range of control surfaces). In this design, the regulation referred is CS-22 [8]. Some paragraphs considered in designing the flight control system are **Subpart C - Structure** concerning **control surfaces and structures** (CS.22.395 and CS.22.397) and **Subpart D – Design and Construction** concerning **control surfaces** (CS.22.655 and CS.22.657), **control systems** (CS.22.671 to CS.22.713), and **cockpit design** (CS.22.777 and CS.22.779).

In gaining design knowledge, literature studies were accomplished in this research such as flight manual and maintenance manual of some gliders as well as some references in building home-built aircrafts [9-15]. Survey to some gliders available in Indonesia was also done to obtain a benchmark.

Flight control mechanism and kinematics are design and simulated in such a way that they comply with space availability. Whereas the selections of type, dimension, and material of the components of flight control system are based on loads computation, weight, durability, price, and availability in the market.

3. Flight control mechanism design

The modern high-performance sailplanes commonly use combination of push-pull rod, torque tube, and crank as the main components for control mechanism. Steel cables use is limited to rudder and tow mechanism. The design of flight control system mechanism of GL-1 includes mechanism and kinematics of elevator, ailerons, and rudder as primary flight controls as well as wing-flaps and airbrakes as secondary flight control. The design results are explained in the following subsections.

3.1. Control column

A centre-stick is selected as control column for the reason of familiarity 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 is not possible due to very limited space owing to the existence of tow mechanism and landing gear. Motion transfer generally uses a mechanical system, which uses a torsion bar or a crank. In the compared airplanes there is one commonly used configuration, namely the use of torsion bar to connect to the elevator mechanism. Meanwhile, to connect to the aileron mechanism uses a combination of a crank and push-pull rod. Other configurations are the use of crank and push-pull rod as in elevator mechanism on DG300 and the use of torsion bar as in aileron mechanism on ASK-21. In the design of control column for GL-1 the first option is selected because of less complexity while still fulfilling the function.

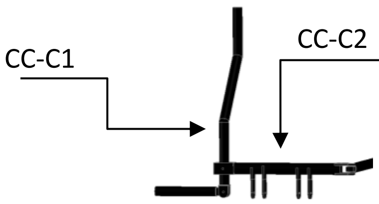

Figure 1. Three view drawing of control column, connected to elevator and aileron mechanism.

Control Column consists of two parts (See Figure 1).The first part of the control stick (CC-C1) works as a stick that is held and controlled by the pilot and can be moved forward- backward and left-right with a displacement of 5" or a deflection angle of the stick 25 deg. CC-C1 is connected with CC-C2 at the rotating axis, and also connected to the aileron mechanism through the lower end of the control stick. Elevator control is connected via CC-C2. The second component (CC-C2) works as a connector of the control stick (CC-C1) to control the elevator. CC-C2 is connected to the elevator rod at the right end.

3.2. Elevator mechanism

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 [12] is selected 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 replaced with simpler and cheaper fork end terminal.

In the GL-1 elevator mechanism design, at least two crank groups are needed. One crank system is used for transferring motion from the bottom of the cockpit to the midpoint of the fuselage. Another crank system is used to change the direction from front/back movement to up/down movement at the vertical fin.

Initial sizing is done after the configuration is determined. Initial Sizing is done by estimating the location, crank dimensions, and rod dimensions based on comparison planes. The location is then fixed by considering the existence of support such as spars, torque tubes of other mechanisms, etc. The crank dimensions are then changed so that full deflection of stick gives 30 deg deflection of elevator.

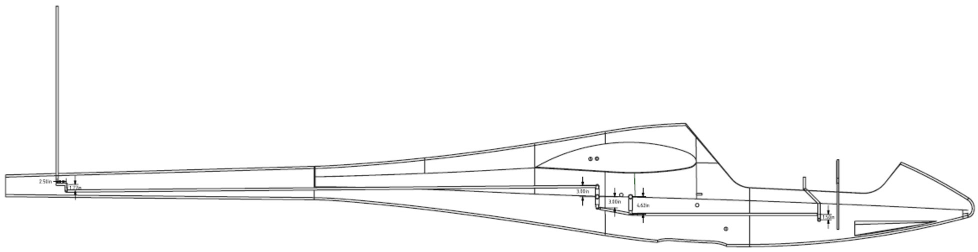

Figure 2. Elevator mechanism.

3.3. Aileron mechanism

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 important parts of the aileron mechanism, namely: the fuselage mechanism, the wing mechanism, and the connection.

The type of connection determines the fuselage mechanism and the wing mechanism. There are two types of connections, using torque tube or crank. In GL-1, due to the limited space in the wing, the crank type connection with vertical motion is selected. Such a mechanism is used also on Glasflügel-made planes like Libelle and Schempp-Hirth like Arcus [13]. However, the mechanism used is a mechanism specifically designed for the flaperon mechanism with airbrake flap, although it is also used in some aircrafts that have conventional spoiler configurations and aileron without flaps.

To be able to transfer the movement of horizontal translation from the control stick to a vertical translation at the connection, a rotation mechanism is required in the fuselage mechanism. To shorten the development time, the mechanism on the Libelle plane is referred with simplification accommodating the control surface configuration on GL-1. The right and left mechanisms need to have a different direction deflection, hence a mechanism that give different direction of rotation is made.

The mechanism in the wing is sufficient with a push-pull rod to the first wing segment where the aileron installed. Crank is made in such a way that the rod mechanism pulls the aileron through the underside of the wing. Initial sizing is done after the configuration is determined. Initial Sizing is done by estimating the location, crank dimensions, and rod dimensions based on comparison planes. The location is then fixed by considering the existence of support such as spars, torque tubes of other mechanisms, etc. The crank dimensions are then changed so that full deflection of stick to the right gives 10 deg up of right aileron deflection and 25 deg down of left aileron deflection, and vice versa.

In addition to the right and left mechanisms must have the opposite deflection, the aileron mechanism must also be able to produce different deflection values for up and down. This is obtained by using the crank configuration shown in Figure 3. This configuration is also used by other gliders which have similar aileron configurations. If the crank is rotated then the rotation will be transferred into vertical motion to the aileron mechanism on the wing. Because two similar cranks have different angles, one forward and one back, if both rotate in the same direction, they will have different vertical displacements. This is used to get different aileron deflection values when deflection up and down. The ratio of maximum value of up and down deflection of the aileron can be varied by changing the x angle. The results of deflection variations with a constant crank length can be seen in the table below. It should be noted that the smaller the angle, the heavier the load received by the rod. This gives a problem at the beginning of initial sizing using a 30 degree angle, the resulting load is too heavy so there is no configuration of the chromoly tubing structure that can withstand the load. Therefore, the angle of 35 degree is selected which gives the right deflection ratio and the load value that can still be resisted by the chromoly tube structure. The deflection value is then set so that the desired deflection value is obtained.

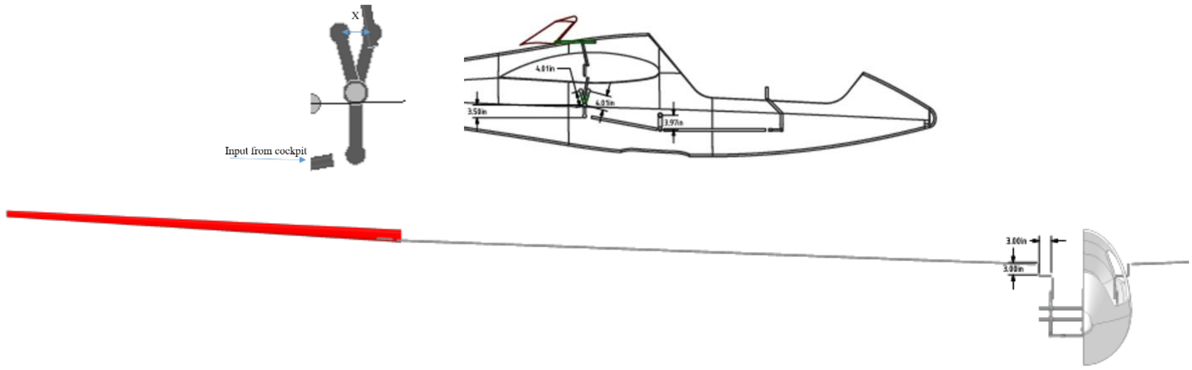

Figure 3. Aileron mechanism.

3.4. Rudder mechanism

Steel cables are commonly used for rudder mechanism of glider, which connecting pedals to the rudder. Cable mechanism is used in the design of rudder mechanism of GL-1. The need of implementing adjustable pedals becoming a reason of selecting heel-toe type pedals for this design. This type of pedal is actuated by rotating, instead of pushing, the pedal forward. It is design so that forward deflection of right pedal gives rudder deflection to the right.

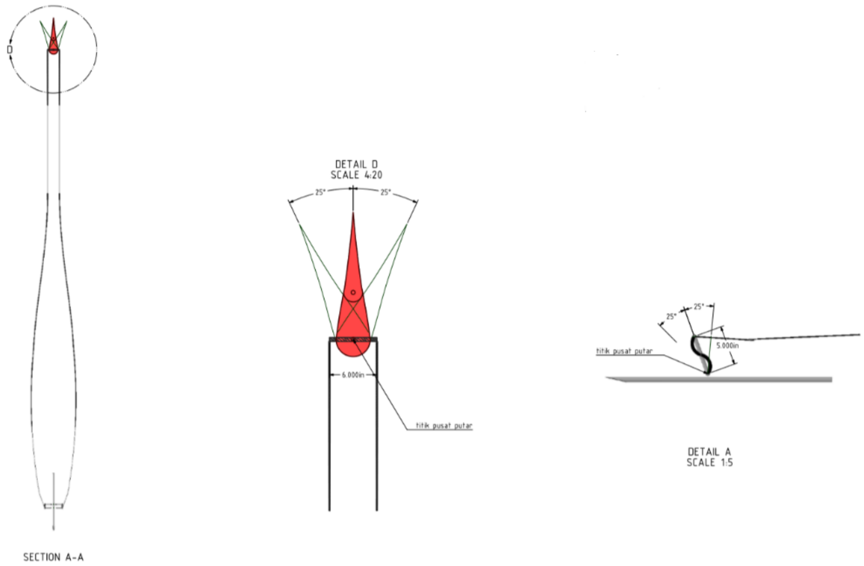

Figure 4. Rudder mechanism.

3.5. Flap mechanism

As in aileron mechanism, there are also three important parts of the flap mechanism, namely: the fuselage mechanism, the wing mechanism, and the connection.

A connection which is commonly used is a torque tube. The use of a torque tube makes it easy to synchronize the movement between the right flap and the left flap. For mechanism in the wing it is sufficient to attach the rod at the top of the torque tube to push the flap to the desired position.

The flap lever is placed at the left side of the cockpit for operation with the left hand. The pilot pulls the lever to extend the flap. This lever moves the rod and then rotates the torque tube on the flap joint.

Initial sizing is done after the configuration is determined. Initial Sizing is done by estimating the location, crank dimensions, and rod dimensions based on comparison planes. The location is then fixed by considering the existence of support such as spars, torque tubes of other mechanisms, etc. The crank dimensions are then changed so that full deflection of flap lever gives 25 deg deflection of flaps.

Initially, it is intended to have 10” of maximum lever deflection, The problem with flap mechanism is that it is difficult to reach flap lever movement to 10”. The second problem is ensuring that the maximum deflection reaches 25 degrees. The main problem is that in the first crank design, there is a certain point where if it is deflected further it will cause the flap deflection to return to zero again. In this design, the point is obtained at 7.5-inch lever deflection. Alternative solution by changing the crank length is not possible because it is very close to the frame/bulkhead of the seat. Therefore it must be ascertained that the 7.5-inch lever deflection will result in 25 degrees deflection of flaps. This is also not easy because the first crank problem also appears in the third crank flap. After several iterations, the fixed geometry is finally obtained.

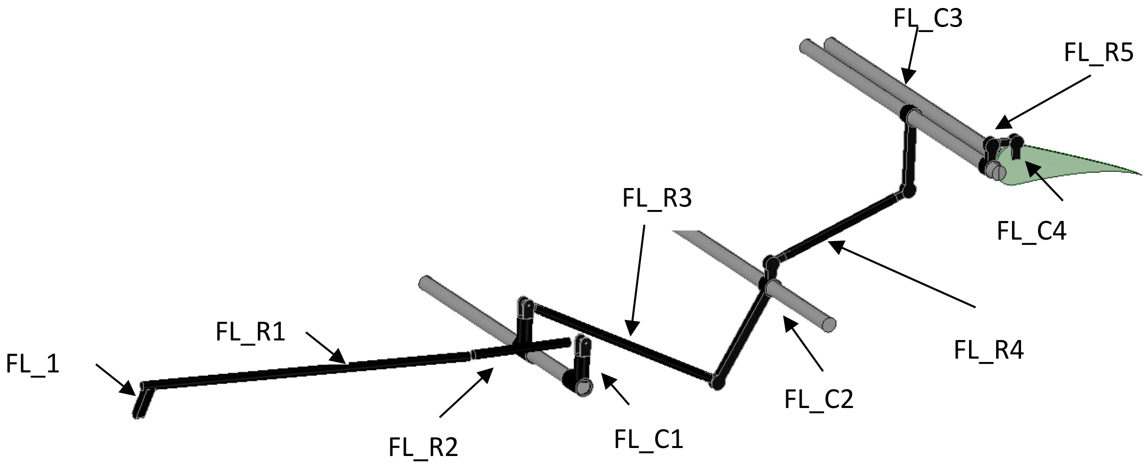

Figure 5. Flap mechanism.

3.6. Airbrake mechanism

As in aileron mechanism, there are also three important parts of the flap mechanism, namely: the fuselage mechanism, the wing mechanism, and the connection.

Like in flap mechanism the airbrake lever is also placed at the left side of the cockpit. The pilot pulls the lever to extend the airbrake. Initially, it is intended to have 10” of maximum lever deflection. The problem with airbrake is that it is difficult to get airbrake lever deflection up to 10 inches. The main barrier is the crank shape on the fuselage. The airbrake lever deflection can be extended by extending the first arm of the first crank, but the long arm has effect of weakening structure. So far, the maximum lever deflection is 7.5 inches which brings to a full extended airbrake.

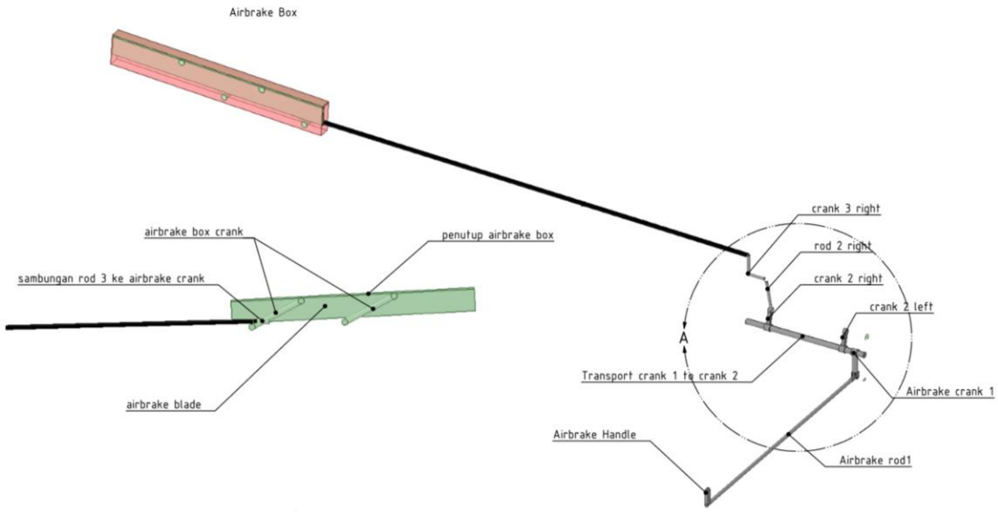

Figure 6. Airbrake mechanism.

4. Conclusion

A design of flight control system mechanism for the national glider GL-1, which includes primary and secondary controls, has been conducted. Mechanism and kinematics of flight control system are designed to comply with regulation as well as space availability. Fully-mechanical flight control system is selected for the aircraft since the aerodynamic forces acting on the glider are not excessive.

Acknowledgement

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