

# Configuration Selection and Conceptual Design of Rudder Control System of a Microlight Aircraft

Mayur Patil<sup>1</sup>, Malisetty Leela Shankar<sup>2</sup>, Veerasha R K<sup>3</sup>

PG Student, Department of Mechanical Engineering, NMAMIT, Nitte, Karkala, Karnataka, India<sup>1</sup>

Senior scientist, CSIR – National Aerospace Laboratories, PB 1779, Bangalore, India<sup>2</sup>

Assistant Professor, Department of Mechanical Engineering, NMAMIT, Nitte, Karkala, Karnataka, India<sup>3</sup>

**ABSTRACT:** In microlight category aircraft the control surfaces such as rudder, elevator and ailerons are generally operated through mechanical flight control system and these controls are provided in the cockpit of an aircraft. The interconnection between the cockpit and the surface is through the routing in the form of cable-pulleys or push-pull rods. Hence there is need for most efficient design of this system to make an effective manoeuvring of an aircraft. In this paper an effort has been made to bring out an efficient rudder control system configuration and mechanical design details of rudder pedal.

**KEYWORDS:** Aircraft, control surfaces, mechanical flight control system, cockpit, and rudder pedal.

## I. INTRODUCTION

In both structurally and operationally aircraft is very complex vehicle and it consist of many control systems such as flight control system, engine control system, environmental control system and etc. Flight control system (FCS) is mainly for the directional control of the flight and FCS is achieved by controlling different control surfaces. FCS is classified as primary and secondary control system. Again primary control system consists of aileron, elevator and rudder control system, the complete details of primary control system is shown in the Figure 1. Ian Moir et al [1].

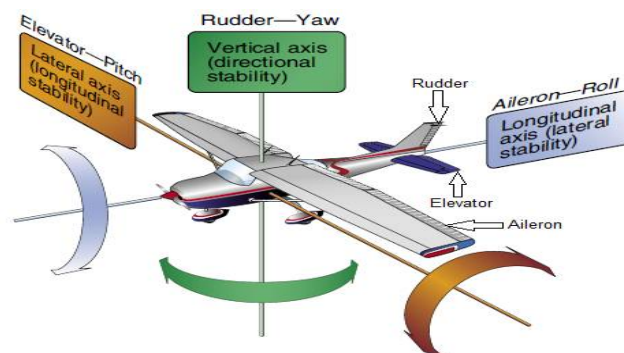


Figure 1: Primary flight control system

## AILERON

Trailing edge of each wing is provided with the aileron surfaces and they are made to move in the opposite direction from each other to control the roll about the longitudinal direction. Ailerons are connected to the cockpit controls through push-pull tubes, cables, pulleys and bell crank. By moving the control stick or wheel to right, aircraft can be made to roll towards right and this is because of deflection of the right aileron to upward and left aileron to downward and vice versa.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 9, May 2016

## ELEVATOR

Elevators are provided at the rear end horizontal tail assembly to control the moment of the aircraft about the lateral direction. These elevators are hinged at the fixed horizontal stabilizer and they are connected to the cockpit controls through control cables. By applying the forward pressure on the control wheel or stick, elevator can be made to move downward and this causes the aircraft nose to drop downwards and vice versa.

## RUDDER

Rudder is a vertical movable surface and it is hinged at the rear end fixed vertical stabilizer or fin. Rudder is connected to the rudder pedal through cable and pulleys. Rudder is mainly to control the aircraft yawing. Rudder surface is made to move towards right by pushing right pedal forward to achieve the yawing of the aircraft to right and vice versa. Ian Moir et al [1].

## II. DESIGN METHODOLOGY

### DESIGN REQUIREMENT

- Microlight has to have dual conventional independent controls with adjustable rudder pedals. H. T. E. Hertzberg et al[5].
- Microlight has to be operable by single pilot also.
- Brake system through Toe brakes.
- Rudder pedal height has to be considered based on normal pilot foot (~200mm from floor).
- Rudder pedal adjustments have to be 80°, 90° and 100°.
- During Rudder application, rudder pedal angular movement has to be 20° and rudder surface angular movement has to be  $\pm 25^\circ$ .

### MATERIAL SELECTION

In any design material selection plays most important role and material is selected based on the application and its mechanical properties such as weight of material, corrosion and embrittlement, fracture toughness and crack growth, specific strength, fatigue, environmental stability, availability and producibility, material costs. In aircraft design mainly aluminium alloy, titanium alloy and steel alloy are used.

#### • Aluminium alloys

Aluminium alloys are mainly preferred in the aircraft structure, almost 80% of the aircraft structure is developed using this alloy because of low weight, high strength, good corrosion resistance and better temperature resistance. These alloys are developed as 2000 to 7000 series and 2000, 6000, and 7000 series are most frequently used in aircraft industries. Aluminium alloys are mainly used in bulk head, stringers and other support structure of the aircraft.

#### • Titanium alloy

In the commercial aircraft titanium alloy comprises 5% of structural weight of the aircraft and its content in the military application aircraft is around 25%. Ti-6Al-4V and Ti-4Al-4Mo-2Sn-0.5Si are frequently used in the aircraft structure and most commonly Ti-6Al-4V is used. These alloys are 40% lighter than steel and 40% heavier than steel alloys and also have good toughness and temperature resistance because of which it is preferred for high temperature applications.

#### • Steel alloy

Application of steel alloys in the aircraft industries is less preferred because of its high weight, less corrosion resistance compared other alloys and also restriction of space availability in some complex areas but these alloys are mainly preferred in the application where high tensile strength is required. Some of the mechanical properties of the different steel alloys are listed in the Table 1. Michael chun-yung niu [2].

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 9, May 2016

**Table 1: Material properties of steel alloys**

Material	Tensile strength (MPa)	Yield strength (MPa)	Density Kg/m <sup>3</sup>	Young's modulus (GPa)	Poisons ratio
4130 steel	670	435	7850	205	0.29
4343 steel	1930	1778	7800	180	0.3

The rudder control system circuit requires high tensile strength because of which Steel 4130 alloy is selected as a material for torque tube, rudder pedal and other components of rudder control system of microlight aircraft. Michael chun-yung niu [2].

### LOADS RESULTING FROM LIMIT PILOT FORCES

The total load acting on the control surfaces resulting from the air and corresponding deflection by the pilot force should not exceed the specified range is shown in Table 2.

**Table 2: British civil air worthiness requirement (BCAR) S397 standard loads**

Control	Pilot force daN	Method of application assuming single lever control systems
<b>Pitch:</b> Stick	75	Push and pull handgrip of control stick
<b>Roll:</b> Stick	30	Move handgrip of control stick sideways
<b>Yaw</b> and other foot Controls	90	Apply forward pressure on one rudder pedal

The rudder control system should be designed for the maximum load of 100daN applied on the pedal in the forward direction. British Civil Airworthiness Requirements - Issue 5 [3].

### STIFFNESS AND STRETCH OF THE CONTROL SYSTEM

The applied pilot force on the control circuit should not reduce the elastic strength of the circuit and cable load should be < 10% braking strength. Cable should be selected for 45daN load. And for other controls cable loads are considered from the Table 3. British Civil Airworthiness Requirements - Issue 5 [3].

**Table 3: BCAR S411 standard loads**

Control	Pilot force daN	Method of force application assuming single-lever control system
Pitch	40	Push and pull handgrip of control stick
Roll	20	Move handgrip of control stick sideways
Yaw	45	Apply forward pressure on one rudder pedal

## III. DESIGN DETAILS OF RUDDER CONTROL SYSTEM

### DESIGN DETAILS OF RUDDER PEDAL

Rudder surface is operated through rudder pedals by both pilot and co-pilots. The pedals are interconnected to ascertain pilot co-ordinated control. The design detail of a typical pedal is shown in the Figure 2. The rudder pedal is a simple L-

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 9, May 2016

shaped welded tube detailed as per regular palm size of the pilot. The pedal adjustment bracket is welded to the pedal and is connected with the locking system with pin supported on slotted spring system. The pedal is hinged to the torque tube; whereas locking system is permanently welded to the torque tube. Once the pedal is moved to the desired position, it gets locked with the locking system and becomes integral part of the torque tube. Springs are provided at each pedal to bring back the pedal to the original neutral position when not in use. Wheel brake application system is provided in the cockpit. They are designed as toe brakes. The brake pedals are in the form of L-shaped tubes hinged to the top of the rudder pedal as shown in Figure 2. The brake cylinders are attached to the torque tube at one end and toe brake pedal on the other end and adjusted to achieve required stroke length for brake application.

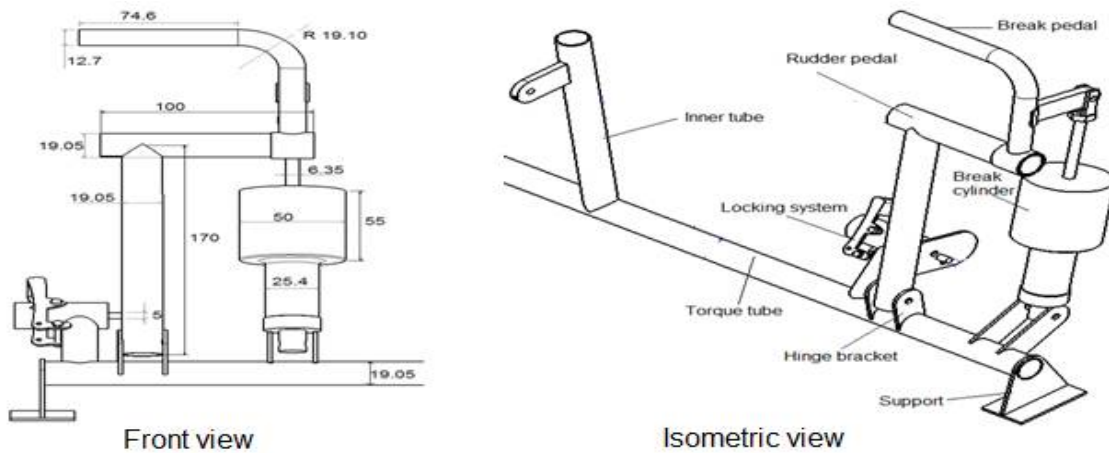


Figure 2: Design details of the rudder pedal

### RUDDER PEDAL ASSEMBLY IN THE COCKPIT

Rudder is made operable through rudder pedals for both pilot and co-pilots. The pedals are interconnected to ascertain pilot co-ordinated control. The same side pedals of each pilot are placed on two torque tubes which lay one behind the other. The schematic of the cockpit rudder control mounting is shown in Figure 3.

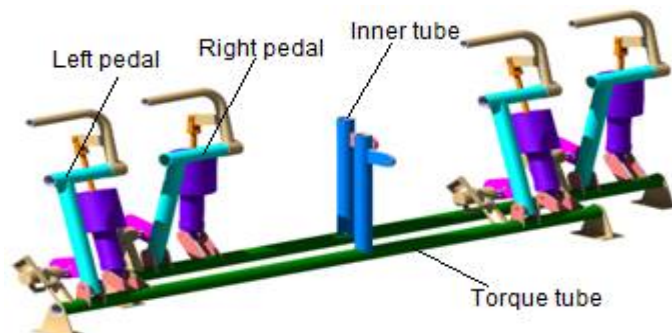


Figure 3: Rudder pedal assembly in the cockpit

### SIMULATION OF RUDDER PEDAL

The pedals are made adjustable as the seats are fixed to meet the comfort of the different pilot height. The pedals travel angularly while adjustment. Care has been taken to adjust the pedals for maximum and minimal travel based on statistics of shortest and tallest pilots (Adjustment angles:  $-10^\circ$ ,  $0^\circ$ ,  $+10^\circ$ ) and this is shown in Figure 4.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 9, May 2016

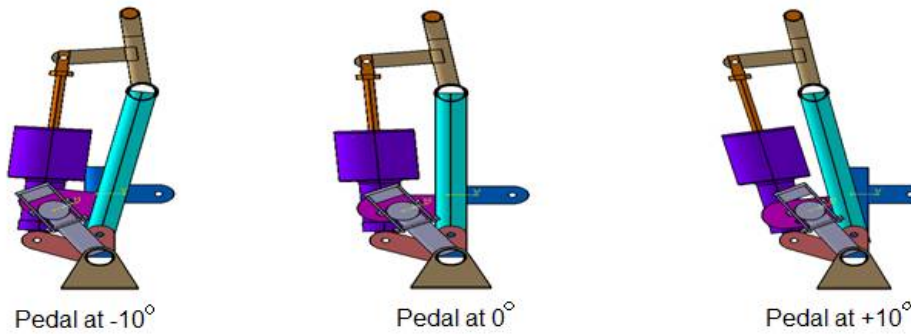


Figure 4: Pedal positions at different angles

## CABLE AND PULLEYS

For Selection of Cable, Table 2 BCAR S411 is considered. Cable load should be  $< 10\%$  of its braking strength and the maximum factor of safety of 2.0 should be applied on the cable selected for the primary control system of the aircraft. The diameter selected for the cable is 3.2mm and total length of the cable used in the routing is around 4.8m. Turnbuckles are provided on each cable to adjust pre tension of the cable depending on the temperature effect. The cables are crimped and attached to the tang. The pulley chosen are the phenolic pulleys with metallic sheave and the size of the pulleys selected are corresponding to the cable selected to avoid the miss place of the cable each pulleys are provided with the guard.

## RUDDER CONTROL LINE ROUTING

The rudder control lines are through cable and pulleys to achieve weight saving. The routing lines are routed as the cables are attached to the centre of the each torque tubes, the guiding pulleys are provided at the centre of the cockpit to achieve the optimum routing with minimum compromise on the stretch and other issues, which facilitate the cable to run through the cockpit to the surface and this is shown in Figure 5.

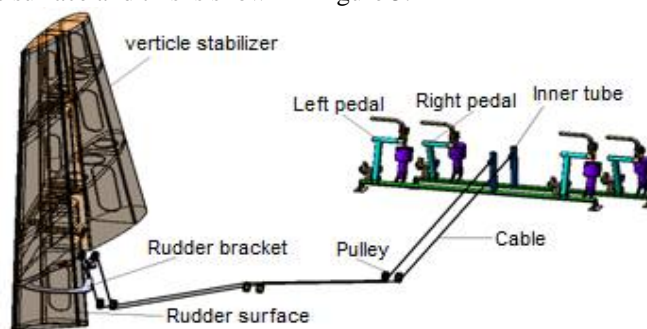


Figure 5: Rudder control line routing

Sufficient support brackets for each of the pulleys are given. Care has been taken not to exceed the maximum angle between two pulleys by  $20^\circ$  to avoid slippage of cables from the pulleys. Also support brackets are designed such that, they act as cable guards, in the event of cable slippage. The complete rudder circuit design is shown in the Figure 5.

## IV. RESULTS AND DISCUSSION

The length of inner tube be  $R_1 = 150\text{mm}$  and angle turned by the torque tube for the application of 900N force on the rudder pedal be  $\theta_1 = 20^\circ$ ,  $R_2$  is the mean radius of the pulley and  $R_3$  is the radius of rotation of rudder bracket about the fixed vertical stabilizer, then angle of rotation of the rudder bracket for the applied load is tabulated in the Table 4.



# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 9, May 2016

**Table 4: Results**

Length of the rope driven (L)	Angle of rotation of pulley ( $\theta_2$ )	Angle of rotation of rudder bracket ( $\theta_3$ )
52.63mm	174.58°	25°

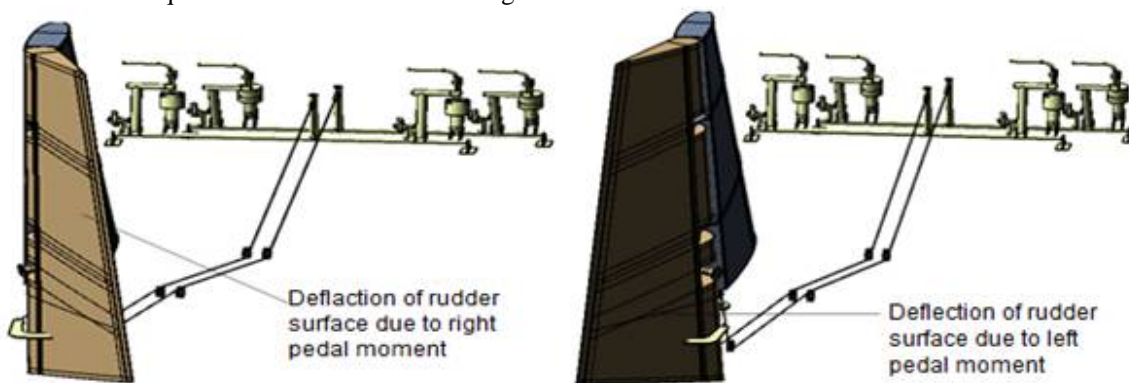
Where,

$$L = R_1 \times \theta_1 \quad (1)$$

$$\theta_2 = \frac{L}{R_2} \quad (2)$$

$$\theta_3 = \frac{L}{R_3} \quad (3)$$

The above results shown in table 4 says that total angle of rotation of rudder bracket is 25° for 20° rotation of torque tube. Here the rotation of the rudder bracket is corresponds to the angle of rotation of the rudder surface about the vertical axis of the fixed stabilizer and hence with this configuration we can expect 25° rotation of the rudder surface for 20° rotation of torque tube and it is show in the Figure 6.



**Figure 6: Deflection of the rudder surface**

## V. CONCLUSION

Proposed rudder control system meets the design requirements of microlight aircraft and also provides the satisfactory manoeuvring of the rudder surface. The pedal adjustment system provided helps to meet the comforts of the different pilot's height. With this configuration of rudder control system 25° of rudder surface angular moment can be expected for the 20° rotation of torque tube by the rudder pedal.

## REFERENCES

- [1] Ian Moir Allan Seabridge., "Aircraft Systems – third edition", John Wiley & sons, Ltd, England, 2008, pp 1-11.
- [2] MICHAEL CHUN-YUNG NIU., "Airframe structural design – second printing", Lockheed aeronautical systems company Burbank, California, 1988, pp 90-110.
- [3] Civil Aviation Authority., "British Civil Airworthiness Requirements - Issue 5", TSO (The Stationery Office), Norwich, 2009, pp 5-8.
- [4] R.S. KHURMI J.K. GUPTA., "Machine Design – 14 editions", EURASIA PUBLISHING HOUSE (PVT.) LTD., NEW DELHI, 2005 pp 349-353.
- [5] H. T. E. HERTZBERG and FRANCIS E. BURKEL., "Foot Forces Exerted at Various Aircraft Brake-Pedal Angles", HUMAN FACTORS, 1971 pp 445-456.