

Performance Analysis and Design Modification of Engine Power Control Cable Routing of Light Transport Aircraft

Somanagouda PolicePatil M¹, Vinay C A², Vincent D'Souza³, Jayagopal S⁴

PG Student, Department of Mechanical Engineering, NMAMIT, Nitte, India¹

Scientist, C-CADD, CSIR-NAL, PB 1779, Bangalore, India²

Asst. Professor, Department of Mechanical Engineering, NMAMIT, Nitte, India³

Senior Scientist, C-CADD, CSIR-NAL, PB 1779, Bangalore, India⁴

ABSTRACT: Power levers are mechanically connected to corresponding levers on engine, through ball bearing control cable called Flexball. Engine power is controlled by power lever in the form of angular movement from the cockpit based on the flight condition. Cable friction is function of cable length and bend angle. Thus, cable routing should be followed with precise routing methodology to reduce the pilot effort in selecting particular power settings for a given flight condition. In this paper, existing power control cable routing has been modelled, carried out kinematic analysis and proposed design mods to power control cable (PCC) routing by reducing friction and thus maximizing the transmission efficiency.

KEYWORDS: Engine, Power control cable, Friction, Kinematics, Flexball, Fuel control unit.

I. INTRODUCTION

Torque produced by the engine is controlled by the Power Lever Angle (PLA) which is set by the pilot. The power lever is one of the three primary engine control levers present on the quadrant box in the cockpit. The max forward position of the power lever corresponds to maximum power and the max backward position corresponds to reverse thrust. There are two power levers present in the cockpit for left and right hand engines respectively. A constant speed propeller is fitted to these engines which transform the power produced by the engine into thrust. In the existing engine control system, the power lever cables from the engine is directly connected to the power levers on the throttle quadrant box as shown in Figure 1. The power lever cable is connected to the cam box on the engine which is then connected to the Fuel Control Unit (FCU) to control the power produced by the engine. The movement of the power lever in the cockpit is transmitted to the power lever cables through the cam and thereby the desired torque settings are obtained.

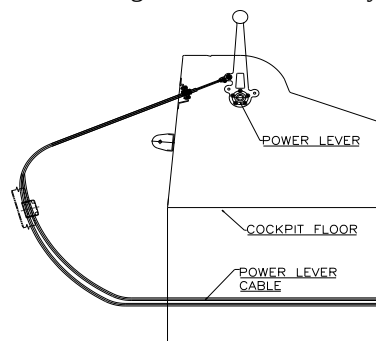


Figure 1: Quadrant box

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 9, May 2016

The torque produced by the engines was plotted with respect to the Power Lever Angle (PLA) and the power lever was found to be highly sensitive at higher power settings and also there is a considerable difference in the repeatability of the PLA position during torque change from flight idle to full power and vice versa as shown in Figure 2. It was proposed to carry out the performance analysis of the engine control cable routing and provide acceptable design modifications to reduce the friction and backlash in the system.

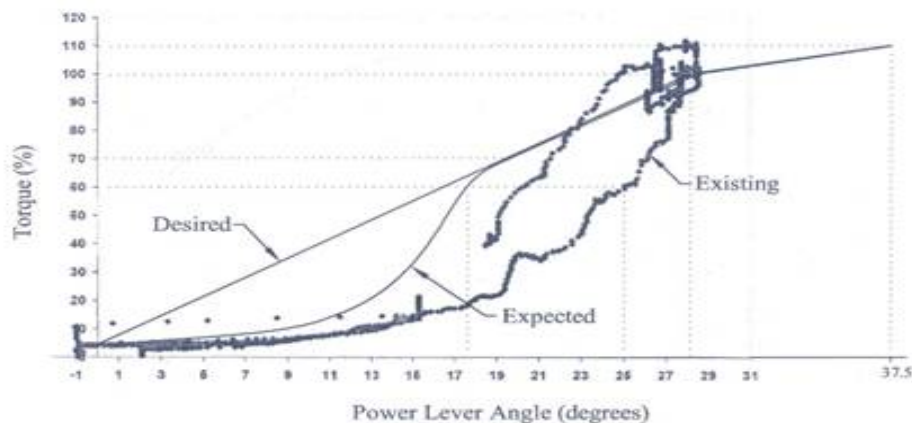


Figure 2: Power lever angle vs torque.

A) FLEXBALL CONTROL CABLES

The operating system is a connector between an aircraft and its engines. Although FADEC (Full Authority Digital Engine Control) play a very important role in the aircraft operating system, manual mechanical steering system is still widely used in some of the low speed and transport aircraft for its simple structure and reliable operation. Flexball is a self-contained system from one end to the other to transmit linear motion under tension and compression loads, Yang Kun et al [1]. Figure3. Shows the construction details, it consists of one central blade which is an active element to transmit motion under compression and tension loads. It is guided by means of two ball cages between two outer races. The entire assembly is housed in a flexible outer sheath. All the components are made of stainless steel. Its main advantage is no adjustments and lubrication is needed during its operating life. Cable friction is a function of cable length, bend angle, operating force and backlash and are affected by load. In accordance with cable manufacturer installation specifications, the control cable routing has to be done.

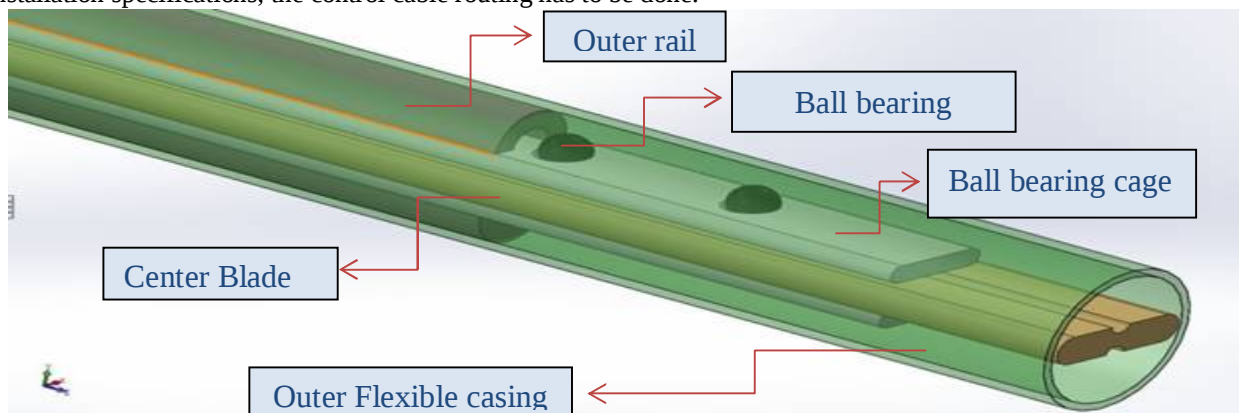


Figure 3: constructional details of Flexball cable.

The cable can be routed through at three dimensional planes with support brackets. Typical transmission efficiency of Flexball cable is between 85% and 95% when the compound bending angle is maintained in the range from 270° to 540°. Operating temperature range is -42°C to 300°C without PVC covering, offering negligible effect on performance.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 9, May 2016

II. METHODOLOGY

- On aircraft the PCC routing study and insitu measurement of PCC operating parameters such as bend angle, bend radius, number of supports and PLA vs FCU angle.
- 3D Modelling of the PCC routing using commercial CAD software.
- Simulation of the PCC model for the existing condition and validation.
- Carried out the sensitivity analysis for various design factors (such as bend angle, bend radius and applied force) affecting the efficiency of the given cable routing.
- Proposed the design improvement to reduce the backlash and increase in transmission efficiency based on the sensitivity analysis.

A) AIRCRAFT PCC ROUTING STUDY AND INSITU MEASUREMENT:

Table 1: Interpretation of the Experimental Data

Serial No.	Quadrant box side PLA, °	FCU angle, °	Quadrant box side, PLA linear displacement, mm	Engine Side, FCU linear displacement	Backlash, mm	Transmission Efficiency	Design Requirement
1.	0	0	From idle to max 83mm	66mm	4	80%	90%
2.	5	5					
3.	10	15					
4.	12	20					
5.	14	25					
6.	15	27.5					
7.	16	30					
8.	18	32.5					
9.	20	37.5					
10.	21	40					
11.	22	42.5					
12.	25	47.5					
13.	28.7	52.5					

The measurement of input power lever angle on the quadrant box is carried out by use of a graduated scale pasted on the quadrant box cover plate. Similarly a special graduated protractor is fabricated and installed on the FCU. For the known PLA movement angle, FCU movement angle was recorded for the complete range of engine operation. Measured data is tabulated in Table 1. Force required for moving PLA from idle to max is 2.5 Kgf (24.52N) and the resistance load from the FCU is 0.3Kgf (2.94N). Measured compound bend angle is 664.5° & minimum bend radius measured is 195mm.

It is cleared from the Table 1. That there is a scope to improve the PCC routing to reduce the losses in the system. Thus sensitivity analysis of various guiding parameters needs to be carried out to improve the performance of the system.

B) 3D MODELING OF THE PCC ROUTING:

A detailed 3D modelling was generated considering all the support structures, bend angles, minimum bend radius etc. to simulate the operating environment as close to reality.

The cable control system modelling requires the material properties of individual components. Table 2. Describes the cable material properties and major specifications.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 9, May 2016

Table 2: Description of the cable material and specifications of the cable

Serial. No	Description Of the Cable	Specifications of cable
1	Total Flexball Cable Length	14m
2	Minimum Bend Radius	195mm
3	Using Stroke	70mm
4	Using Load	60N
5	Limit load	2790N
6	Operating temperature range	-42 ⁰ C to 300 ⁰ C
7	Ball Bearing Control	Stainless Steel
8	Ball Cage	PTFE
9	Casing, Fixed end Fittings & Swivel Assembly	Stainless Steel
10	Outer Coating	Poly Vinyl Chloride(PVC)

1. Solid Modelling and Assembly

The length of the cable is 14m which is routed from central pedestal of cockpit to engine via nacelle through fuselage and stub wing. The solid parts are created by using part design commands of SOLIDWORKS CAD software. The end fitting such as power lever at cockpit, side support brackets and engine side lever were also modelled. This routing has been done to simulate the response of the Flexball cable from throttle lever to the engine is as shown in the Figure 4. The outer diameter of the casing is 8mm and ball bearing size is 2.5mm each at interval of 190mm. cross section of the power control cable, it includes four main parts i.e. outer flexible casing, second inner race, ball bearing, main core and ball case.

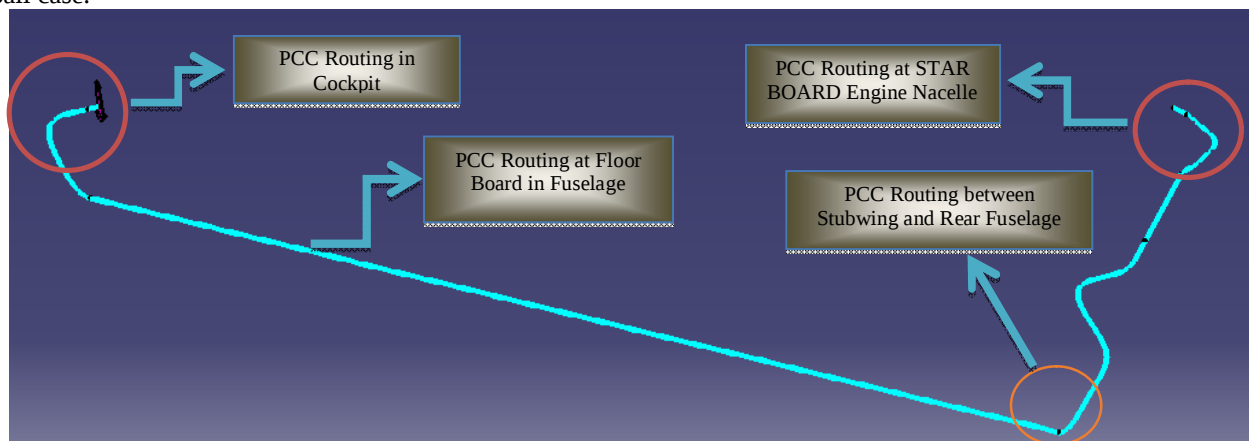


Figure 4: Complete routing of the PCC

C) SIMULATION OF THE PCC MODEL FOR THE EXISTING CONDITION AND VALIDATION:

In the simulation suitable linear motor is selected for kinematic analysis check of the system. Motion is defined to the model to check simulation using motion study commands of SOLIDWORKS CAD software. To perform kinematics suitable boundary conditions were selected and tabulated in Table 3. From the measured data it is found that the total compound bend angle is 710°, Minimum bend radius is 100mm and number of support clippings are 25 at different intervals. Dennis W. Hong et al [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 3: Boundary Conditions of the Cable System

Description of the cable	Boundary conditions
Centre blade	Translation motion
Ball bearings	Revelatory motion
Outer flexible casing	Fixed
Outer rail	
Ball bearing case	

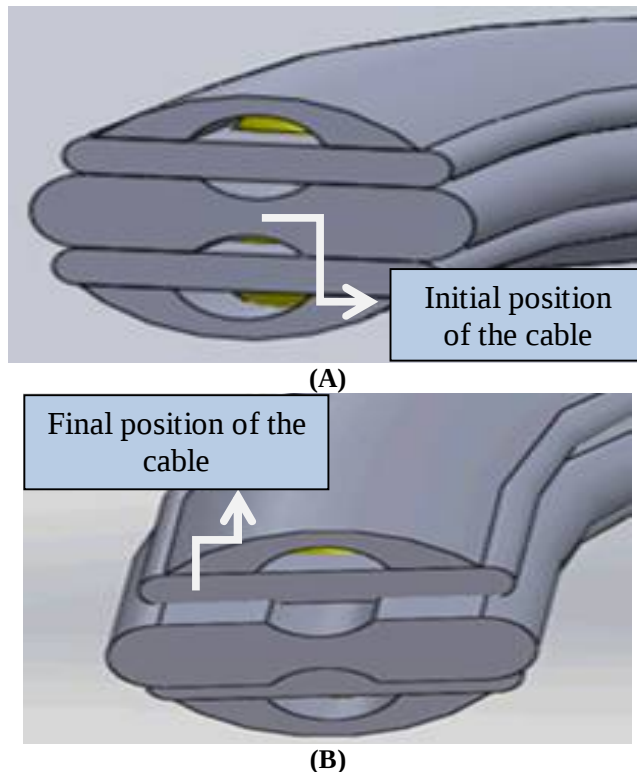


Figure 5: Kinematic simulation of the PCC A) Initial position, B) Final position

The Figure 5. (A) & (B) shows that the kinematic simulation of the PCC; the outer casing is not shown for clarity and to show the clear movement of the inner race. Simulation was carried out for the actual conditions and routing methodology as on the aircraft. Input data is as in section II (A).

D) SENSITIVITY ANALYSIS FOR VARIOUS DESIGN FACTORS:

Numbers of iterations were carried out with the combination of variations in bend angles, bend radius and clipping points to arrive at an optimum routing scheme without calling for a major modification on aircraft. Simulations have shown that bend angles below 540° reduces considerable loss also by varying the number of clipping points and its interval, friction can be reduced.

From the optimum routing it is found that for the PLA movement of 83mm, FCU side linear displacement is 75mm which has improved the transmission efficiency by 10%. Once the proposed routing is implemented on the aircraft, test can be conducted to find the actual transmission efficiency and simulation model can be further improved. Yang Kun.et.al [1], A.C.J Luo.et.al [3].

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: Correlation between FCU angle on the engine & PLA.

Angle on Engine (Degree)	PLA (degree)
0	0
5	2.64
10	5.23
15	7.85
20	10.37
25	13
30	15.61
35	18.17
40	20.72
45	23.19
50	25.61
55	28
58	31
60	33
62	37.5

III. CONCLUSION

Existing power control cable routing has been modelled and simulated as per the measured data on the aircraft. Different configurations and combinations of driving parameters were simulated to arrive at a feasible routing technique which shows that there is significant reduction in the transmission loss. From simulation results for the improved routing, transmission efficiency is estimated is 90% which can be tested after implementing proposed improvements in the power cable routing on the aircraft. From Table 4 the response between PLA and FCU angle has improved. Thus the proposed design modifications are satisfactory.

REFERENCES

- [1] Yang Kun, Tu Qiuye and Cai Yuan Hu. "Performance analysis of ball bearing controls for engine operating system", 29th congress of the international council of the Aeronautical sciences, September 7th 2014.
- [2] Dennis W. Hong and Raymond J. Cipra. "A method for representing the configuration and analyzing the motion of complex cable-pulley systems", Journal of Mechanical Design, Vol. 125, 332-341, June 2003).
- [3] Xiaolei Yin and Alan P. Bowling. "Dynamic Performance Limitations Due to Yielding in Cable-Driven Robotic Manipulators", Journal of Mechanical Design, Vol. 128, 311-318, January 2006.