Application of active control technology to aircraft control surface

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ABSTRACT

In this paper, the application of active control technology to control a control surface of aircraft has been developed. The simple rudder control surface of aircraft is designed and fabricated with a feedback mechanism. To improve the efficiency of movement of rudder control surface to the correct position without any deviation, the active control system is applied. In this developed model position of control surface will be corrected to relative deviation with the help of micro controller, stepper motor, rack and pinion mechanism. This provides better and effective performance of the controls can be achieved for smooth flight of aircraft. In this paper, the designed and developed model of active control mechanism improves the performance of the rudder control surface movement.

KEY WORDS: Active control technology, Avionics, control surface, micro controller, stepper motor, rack and pinion.

1. INTRODUCTION

The field of aeronautical engineering began to foresee its advancements in the future. Various new modern technologies and techniques were discovered and implemented almost in all branches of aviation industry. One branch where the researchers are continuously working for further more development is in aircraft Systems with Avionics. Many new ideas are continuously being proposed. This paper deals with the conceptual design of active control technology of control surfaces of aircraft. The intent of this paper is to develop a design of control system with feedback mechanism which can be used to minimize error in deviations of control surfaces of aircraft. Mainly there are three control surfaces such as ailerons, elevators, and rudders. Rudder operation is quite critical than the use of elevator. So that the complicate design of rudder has been designed in this work. As rudder control is so sensitive, the feedback mechanism also along with the rudder control is developed. The error in deviation of control surface is sensed with help of suitable sensor and it can be minimized by PIC micro controller. In this concept, stepper motor is used for controlling rudder deviation with driver of motor. This idea is inspired from automobile industries which use active controls.

An Overview over active control technology: A technology in which a signal generated by the movement of the control column is fed into a computer, which in turn integrates various parameters and gives the output signal to the control actuators for the particular flight regime. Flight controllers fitted in the aircraft are operated by the actuators. Programming is done to take control of displacement and force characteristics felt by the pilot. This type of control system is adopted in the fly by wire system of the modern aircraft. The conventional control sticks fitted in the aircraft, which are passive controls. The force applied by the pilot is directly transmitted to the actuators to control the movement of control column in the flight deck. The stick is fitted by springs and dampers which is programmed to feel the movement of control surface.

Conceptual design of active control technology to control surfaces of aircraft: The active control technology used in the automobiles brought about a new idea in the aviation industry. In this study, it is preferred in the rudder control surface, where the control system is designed in such a way that it performs active control of rudder for yawing moment. The accuracy of moments given by pilot on control surfaces is much important for effective flight of aircraft. This is achieved by active control technology which as feedback system for control systems of control surfaces.

Here in this concept, various components are used on avionics basis as PIC micro controller-16F877A, tachometer sensor, potentiometer b100k, driver-7414, four leg micro switches, and display unit. Potentiometer is an electrical component called as a variable resistor which works as control stick of pilot which gives value of required deviation in degree. Also stepper motor is used to actuate rudder by using rack and pinion mechanism. Instead of stepper motor, hydraulic system can be used which is commonly used in today's aircrafts. But stepper motor installation will be cheaper than hydraulic system. The only major advancement made here is that the attachment of tachometer sensor on pinion attached to stepper motor which will be connected to PIC micro controller. This is the point where error will be estimated by PIC micro controller. Once required degree of deviation which has to carry out by rudder is set by pilot stick or potentiometer by varying register, input will store in the micro controller and it will be visible on display unit. Now stepper motor will make deviation of rudder. When pinion will be moving for given input, tachometer sensor will read the actual deflection occurred and this value will be store in PIC micro controller. Further initial and actual readings will be compared and error can be estimated which will be shown on display unit. That error can be minimized by giving correctional input to stepper motor. This process will continue until rudder gets initial deviation. This is well known as active control technology as shown in figure.1.

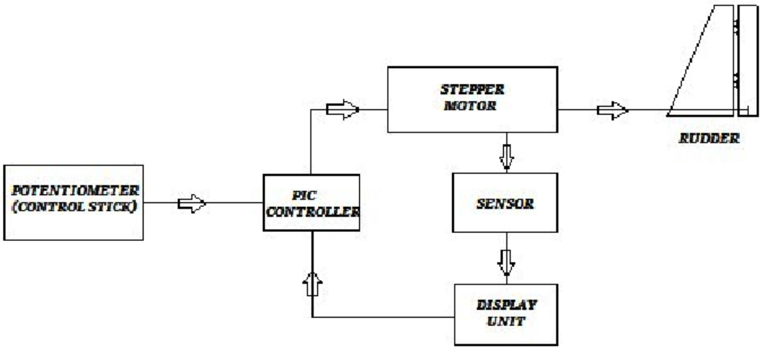

Figure.1. Block diagram of active control

An Overview over control surface of aircraft (rudder): The requirement of rudder surface is to control and trim the direction of aircraft. The directional control is measured through yaw rate (R). Trimming is done to govern rudder deflection within the maximum limit. The design regulations given in FAA for directional control must be addressed by a rudder designer. Here rectangular type of rudder is referred as shown in figure.2.

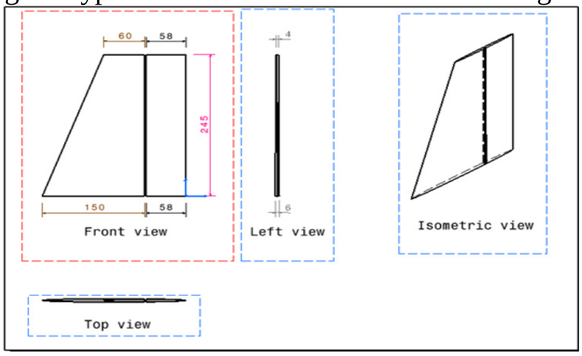

Figure.2. Drafting of rudder design

Mathematical model formulation: The rudder control surface has a moment of inertia J about the hinge, the effective stiffness and damping values of the assembly of stepper motor with rack and pinion mechanism are k and c respectively and the rotation of the control surface is θ. For the given system model the kinetic energy is given by

$$T = \frac{1}{2} J\dot{\theta}^2$$

Strain energy of the spring is

$$U = \frac{1}{2} k(a\theta)^2$$

The damper contribution is defined by the dissipative function

$$\Im = \frac{1}{2} c(a\dot{\theta})^2$$

.By applying the Lagrange equation, the equation of motion is written as

$$J\ddot{\theta} + ca^2\dot{\theta} + ka^2\theta = Q \qquad (1)$$

Q is the active control force to the system by the controller is given in the equation (1).

Power Calculation for stepper motor:

Torque value for stepper motor (T) = 1.853456 Nm
RPM value for stepper motor (N) = 10
Angular speed of pinion (W)
W= (2πN)/60 = 1.04719 rad/sec
Power of stepper motor (P) = T.W
P = 1.853456 × 1.04719 = 1.9409 W

Rack and pinion mechanism: Linear actuator consists of a rack and pinion mechanism which convert rotational motion into linear motion. The small spur gear is called a pinion gear and linear gear tooth on the bar is called rack. Angular rotary motion applied to the pinion drives the rack to move, thereby transmitting the rotational motion of the driving gear pinion into the linear driven motion of the rack.Pinion can move clockwise as well as anticlockwise direction as per programmed driver of stepper motor.

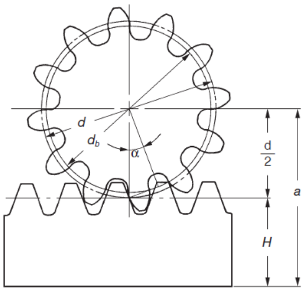

Figure.3. Rack and pinion mechanism

The designed values are given in the table1 for manufacturing rack and pinion mechanism as shown in figure.3.

Table.1. Designed values of rack and pinion mechanism

Module for pinion (m = d/z)	1.7 mm
Pressure angle for pinion (α)	20°
Number of teeth of pinion (z)	24
Coefficient of profile shift (x)	0
Height of pitch line of rack (H)	10 mm
Center distance $a = zm/2 + H + xm$	30.4 mm
Pitch diameter for Pinion (d = zm)	40.8 mm
Base diameter for pinion (db = d cos α)	38.34 mm
Addendum ha = m(1+x)	1.7 mm
Whole depth (h= 2.25×m)	3.825 mm
Outside diameter of Pinion (da = d + 2 ha)	44.2 mm
Root diameter of Pinion (df = da – 2h)	36.55 mm
Length of rack (L)	185 mm

PIC micro controller -16F877A: Programmable Interface Controllers (6) are called as PIC micro controllers. This consists of programmable electronic circuits that can be used to program to carry out a various type of tasks. They are also used as a timer or to control different activities in a production and process line.PIC micro controllers are available in pre-built circuits and kits which are relatively cheap. Assembling of PIC circuit has been done in this model.PIC 16F877A is basic building block based on Harvard architecture. It is one of the most advanced micro controllers from Microchip.

Potentiometer b100k: Potentiometers are the electrical component called variable resistors which are also commonly known as "pots,”. The operation of pots is connected with a knob. When the knob is turned and that the rotational motion is directly changing the resistance in the electrical circuit. This change in resistance is then used to increase or decrease the strength of the electrical signal to do some task. The volume adjustment of an audio signal is an good example. Pots are also employed in the mechanical and electrical equipment which may be larger ones. It is also applicable in consumer electronics. The developed model is as shown in fig 4.The demonstrated reading are tabulated in table.2.

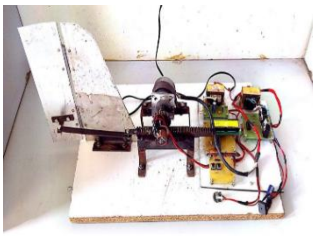

Figure.4. Developed active control rudder model

Table.2. Rudder movement error correction

Input Angle in degree	**Error in degree**	**Actual Deviation in degree**	**Corrected angle in degree**
25	2	23	25
30	0	30	30
20	1	19	20

Various Configurations: This concept is not limited to this design. In this case the hydraulic system, dial gauge type sensor can be installed on control surface which can help to rectify error in deviation of control surfaces. The coding of PIC controller will change as per application of control system and also pneumatic system can be installed but accuracy of output will reduce. Compared to these systems, stepper motor model is cheaper.

2. CONCLUSION

It is evident from the work done, the yaw control as well as other surface controls of an aircraft can be made efficient by active control system using stepper motor. Different components were thoroughly analyzed in a fabrication of rudder active control system for a modern transport aircraft. The developed system has the advantages of real-time control of force feel, smooth, high quality feel, Improved interface to user, carefree handling. This is an excellent working model which can be used for active control technology studies in aviation field. This type of working model can be fabricated using hydraulic system in future with efficient feedback system for various control systems in aircraft.

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