PITCH CONTROL OF AN AIRCRAFT USING LEAD COMPENSATOR & FUZZY CONTROLLER

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Abstract : The paper presents the control of an aircraft in the longitudinal plane using lead compensator and Fuzzy controller. A linearized longitudinal dynamics of mathematical model is necessary for the design of the flight system. Lead compensator has the characteristics of a lead network it improves the transient response of the system. For controlling the pitch angle Matlab – simulink model is used to tune the compensator and Mamdani type fuzzy logic controller (S.N.Deepa and Sudha G.2014) is used to tune the parameter by selecting appropriate fuzzy rules through simulations .The results of simulation is presented in time domain specification and the performance are analysed based on the step response . A comparison is made to identify which control strategy gives better response to the desired pitch angle.

IndexTerms **- Fuzzy controller, Lead compensator, longitudinal dynamics, Aircraft.**

I. INTRODUCTION

The successful invention of aircraft by the Wright brothers gave rise to many researchers in the design of the aircraft dynamic characteristics. From the very limited conditions of the first airplane many technologies and experiments have contributed to the development of the day today's highly performed military, commercial and general aviation aircraft. For achieving the high performance of the flight system, many developments are made on its propulsion system, flight control system, structures, aerodynamics, materials used etc. In general, low flying qualities of aircraft will led to dangerous conditions such as climb, cruise and approach phase. Therefore it is necessary to develop a safe flight envelope for the aircraft. It can be achieved through evaluating the dynamic performance such as stability analysis and control characteristics. This paper focuses on the performance of the lead compensator (A.Nagoor Kani, 1999) and Fuzzy controller (S.N.Deepa and Sudha G, 2014) for the pitch control of an aircraft.

In early days of aviation, continuous monitoring of a pilot is required for the safe flying of an aircraft. The range of the aircraft increases, allowing many hours of flight, it will lead to serious health issues for the pilot due to their constant attention. The rapid advancing technology of aircraft soon adapt the concept of autopilot which is designed to perform some tasks of the pilot. The first autopilot in the aircraft was developed by Sperry Corporation in 1912.The autopilot is also known as pilot assistant. It greatly reduces the pilot's work load by permitting the aircraft to fly straight and on a level course without a pilot's attention. This paper represents the design of an autopilot which controls the pitch of an aircraft. In longitudinal motion, the elevator controls the pitch. The rear part of the tail plane's horizontal stabilizer being hinged to create an elevator, which controls the pitch. They are controlled by the control wheel (i.e., stick). If the wheel or stick is pulled back, the elevators go up, causing the nose to point up and the plane to climb. If the wheel or stick is pushed forward, the elevators go down, causing the nose to point down and the plane to lose altitude. This paper illustrates the design of an autopilot that controls the pitch of the aircraft using lead compensator and a Fuzzy logic controller. For a desired pitch angle, the performances are analyzed based on a common criteria of step response.

II. MODELLING OF AIRCRAFT

The aerodynamic forces and moments acting on the flight vehicle in the body fixed coordinate are shown in figure 1.The applied forces and moments on the aircraft and the resulting response of the aircraft are described by a set of equations known as equations of motion.

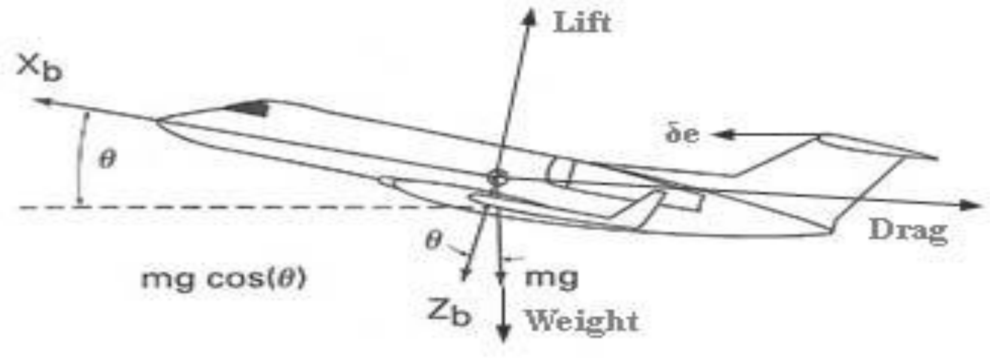

Fig 1.Forces acting on the aircraft

The main forces acting on the aircraft system are gravitational forces, aerodynamic forces and thrust forces. The center of gravity delivers gravitational force therefore the moment about CG is zero. It is necessary to use the longitudinal equation of motion for controlling the pitch of an aircraft. The x ,y, z variables represents the directions with respect to the origin, ie at the centre of the mass of the vehicle. The x axis points to the plane perpendicular to the nose of the aircraft. y axis pointing out of the right wing.The z axis is perpendicular to the x axis which is pointing towards down.The variables $\theta, \varphi, \emptyset$ represents the Euler's angles.The moments components for the roll,pitch,yaw axis are denoted by L,M,N. The variables p, q, r represents angular velocities with respect to the roll, pitch, yaw axis. The u, v, w terms represents the velocitiy components. The angle α is known as angle of attack and angle β represents slideslip respectively. When the plane flies in the atmosphere it is assumed to be undisturbed then the force and moments acting on it is considered as zero. In the longitudinal plane the equation of motion consist of X-force, Z – force and M-moment equations respectively.

Force Equation,

$$X - mg\sin\theta = m(\dot{u} - rv + qw) \qquad (1)$$

$$Z + mg\cos\theta\cos\emptyset = m(\dot{w} + pv - qu) \qquad (2)$$

Moment Equation,

$$M = I_y\dot{q} + I_{xz}(p^2 - r^2) + rq(I_x - I_z) \qquad (3)$$

The equation of motion can be linearized using small disturbance theory (Jisha Shaji and Aswin R.B.Pitch.2015). Assume that the motion of aircraft consist of deviation about a steady flight conditions .This theory cannot be applied to problems in which large amplitude motion are to be expected .The small disturbance theory yields sufficient accuracy for practical engineering purposes. Therefore the equations 1, 2 and 3 should be linearized using small disturbance theory. Then the variables in the equation of motion are replaced by reference value plus a disturbance or perturbation.

$$\begin{gathered} u = u_0 + \Delta u\,,\ v = v_0 + \Delta v\,,\ \omega = \omega_0 + \Delta\omega \\ p = p_0 + \Delta p\,,\ q = q_0 + \Delta q\,,\ r = r_0 + \Delta r \qquad (4) \\ X = X_0 + \Delta X, Y = Y_0 + \Delta Y, Z = Z_0 + \Delta Z \\ M = M_0 + \Delta M \end{gathered}$$

Substituting the values of the stability derivatives in the corresponding equations. Then the state space equation obtained is ,

$$\begin{bmatrix}\Delta\dot{u}\\ \Delta\dot{\omega}\\ \Delta\dot{q}\\ \Delta\dot{\theta}\end{bmatrix} = \begin{bmatrix} X_u & X_\omega & 0 & -g\\ Z_u & Z_\omega & u_o & 0\\ (M_u + M_\omega Z_u) & (M_\omega + M_\omega Z_\omega) & (M_q + M_\omega u_o) & 0\\ 0 & 0 & 1 & 0\end{bmatrix}\begin{bmatrix}\Delta u\\ \Delta\omega\\ \Delta q\\ \Delta\theta\end{bmatrix} +$$

$$\begin{bmatrix} X_{\delta e} & X_{\delta T}\\ Z_{\delta e} & Z_{\delta T}\\ (M_{\delta e} + M_\omega Z_{\delta e}) & (M_{\delta e} + M_\omega Z_{\delta T}\\ 0 & 0\end{bmatrix}\begin{bmatrix}\Delta\delta_e\\ \Delta\delta_T\end{bmatrix} \qquad (5)$$

Linearized state equation is given by equation (5).The corresponding values of the parameters are obtained from datcom software.

III. METHODOLGY

In this section two method of controls for the pitch are established which is the lead compensator and Fuzzy logic controller.

1.1 Lead Compensator

A lead compensator have the characteristics of a lead network. When a sinusoidal signal is applied to the lead network, the steady state output has a phase lead with respect to the input. The lead compensation improves the speed of response, increases the bandwidth and also it reduces the peak overshoot. Lead compensation improves the transient response whereas, there is a small change in steady state accuracy. Mainly lead compensation is provided to make an unstable system as a stable system. The lead compensator transfer function is given by the equation is

$$G_c(s) = \frac{s+Z_c}{s+P_c} = \frac{\left[s+\frac{1}{T}\right]}{\left[s+\frac{1}{\alpha T}\right]} \tag{6}$$

where $T > 0$ and $\alpha < 1$

The block diagram of pitch control using lead compensator is showed in figure .2.

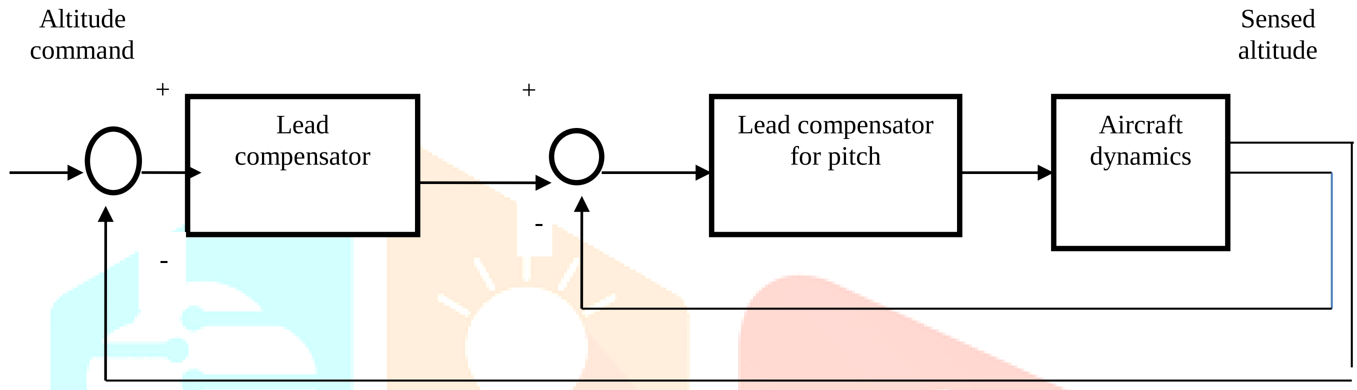

Fig.2 Block diagram of pitch control using lead compensator

1.2 Pitch control of a flight system using fuzzy logic controller

A non linear aircraft system modelling is a very complex process therefore the complexity arises from the uncertainty in the form of indefiniteness. For handling indefiniteness in the existing complex system a fuzzy logic approach is implemented .The first Fuzzy logic was initiated by Lotf A. Zadeh in 1965. It operates in the concepts of membership function. The member function values is given the interval between 0 and 1.To convert the concept of fuzzy logic into algorithms Fuzzy set tools are used. Fuzzy Logic Controller (FLC) can be effectively applied to the wide variety of practical problems. It is mainly used in the context of complex process, generally those that can be controlled by a skilled operator without knowing the information about the system model. The FLC system is carried out in four modules: Fuzzifier ; which is using the membership function to graphically describe a situation. Rule Base; which is the application of fuzzy rule. Defuzzifier; which is obtaining the crisp or actual result and the last module is interface engine. In the concept of interference process there are two main types of Fuzzy interference systems. Takagi Sugeno Kang(TSK) and Mamdani type. Commonly used interference process is Mamdani type because of its simple structure and reasonable results. The block diagram of pitch control using fuzzy controller is shown in figure.3.

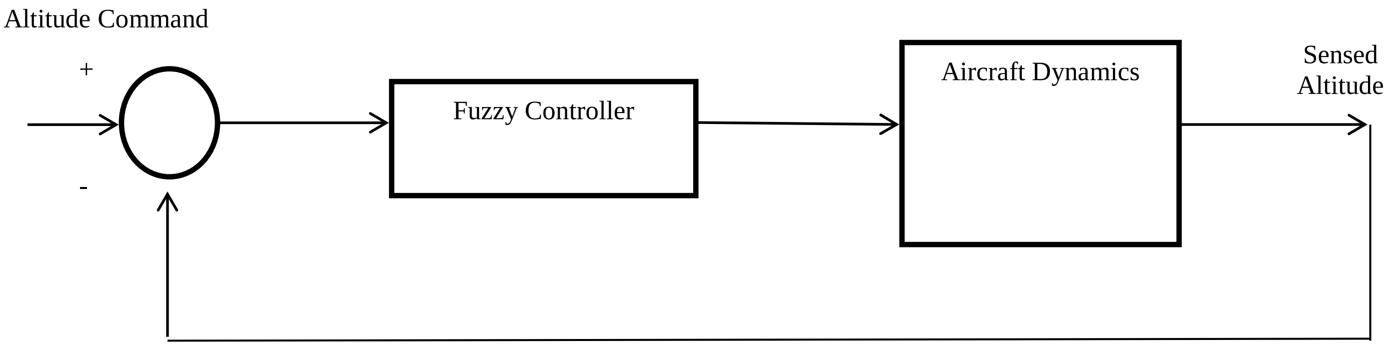

Fig.3 Block diagram of pitch control using Fuzzy Controller

IV. SIMULATION RESULTS

The control schemes are implemented and the corresponding results are presented for the aircraft. The pitch control system using lead compensator and Fuzzy Control Logic has been simulated and the response of the system is obtained.

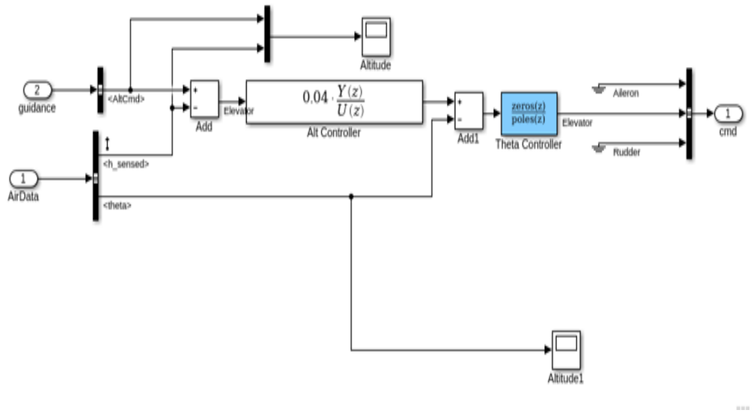

Fig.4 Simulation of the system with Lead compensator

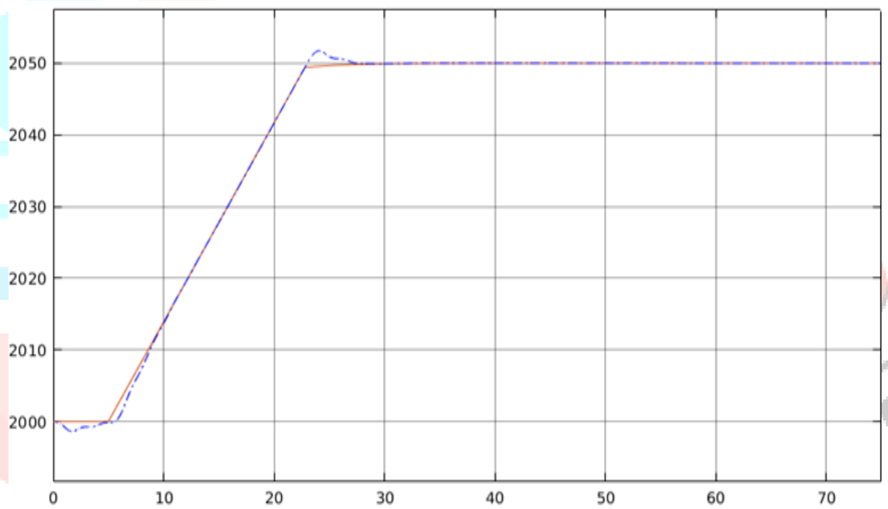

Fig.5.Response of the system using Lead Compensator

Simulink diagram for lead compensator is shown in the figure.4 and their response is given in figure.5. The Response of the system with lead compensator shows that it has a delay time of 7sec, rise time of 15sec, settling time of 28sec, percentage overshoot of 1.4% and the steady state error is zero.

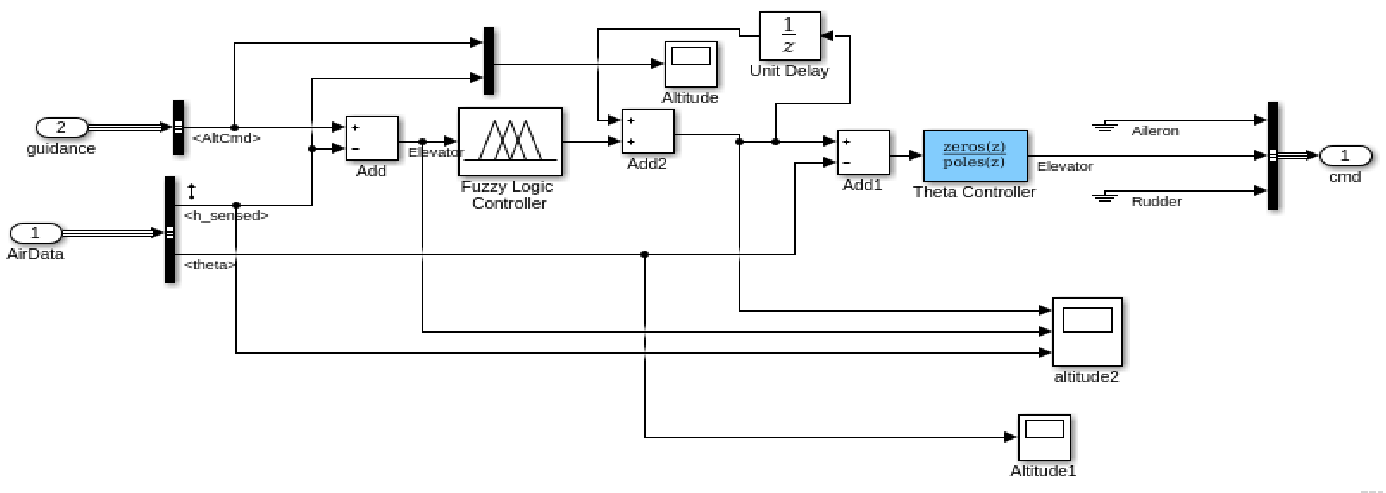

Fig.6.Simulation of the system using Fuzzy Controller

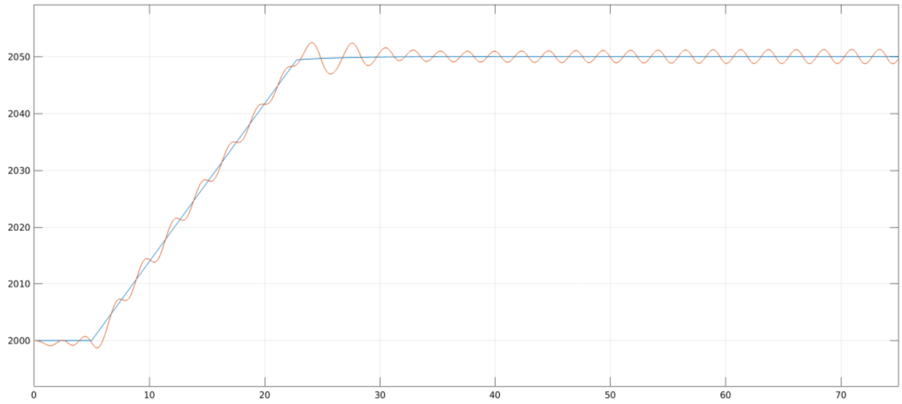

Fig.7 Response of the system using Fuzzy controller

The Simulink diagram for fuzzy controller is shown in figure.6 and their response is given in figure.7.

V. CONCLUSION

Pitch control using lead compensator and fuzzy controller is done.For the lead compensator the delay time is 7sec, rise time is 15sec, settling time is 28sec, percentage overshoot of 1.4% and the steady state error is zero.From the response it is clear that lead compensator gives better performance.

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