International Journal of Research in Advent Technology, Vol.7, No.6S, June 2019
E-ISSN: 2321-9637
Available online at www.ijrat.org

PID Controller Design for Dynamic Motion of an Aircraft

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Abstract—The development and implementation of automatic control systems have helped the aviation industry to grow in more efficient manner in terms of stability and performance of the Aircraft. But as improvement is the key for progress of technology the development and advancement in automatic control systems have also increased. In this paper, the performance of the Proportional- Integral-Derivative(PID) controller is studied for General Navion Aircraft by considering its longitudinal motion. The design is implemented using Model based Programming of MATLAB.. The reference input is the elevator deflection angle and the output is the Pitch angle. The gain values of the Controller is tuned using the PID toolkit. Simulation results shows that the design specifications in time domain and convergence to the design considerations.

IndexTerms— MATLAB, PID controller, Autopilot, Stability and control.

I. Introduction

The introduction of the automatic control systems (autopilots) has played an important role in the growth of civil and military aviation. Modern aircrafts include different types of automatic control systems that help the flight crew in navigation, management and stability augmentation of the aircraft and also reduction the workload on them. The development of the autopilots have also reduced the various flight hazards which was causing the survivability and safety issues. The main motivation to the present work is to the survivability and safety of the passengers in commercial aircraft and safe maneuverability in military aircrafts. A designed controller mustallow acceptable performance in terms of control of the aircraft under a number of shortcoming or fault conditions [3].

There are three basic control moments of aircraft i.e., Pitch, Roll and Yaw which represent both Longitudinal and Lateral motion of the aircraft. These control movements are controlled with the deflection of respective control surfaces present on the aircraft. The Pitch, Roll and Yaw angles are controlled by deflecting Elevators, Ailerons and Rudders respectively. The pitch movement of aircraft is categorized under longitudinal stability whereas roll and yaw are categorized under lateral stability.An aircraft in flight moves along three principles axes namely, the **Vertical axis**which represents Yawing ,**Lateral axis**, which represents Pitching. **Longitudinal Axis**, which represents Rolling. Fig 1 shows the different Axes of the AircraftThe study on stability of the General Navion aircraft using PID toolkit of MATLAB 2014 software is implemented to obtaina optimized results to achieve system stability in [1]. The tuning method of PID Controller like Zeigler-Nichols method is better compared to other methods in improving the stability and performance of flight in all conditions [2], and PID controller has capability of controlling roll motion effectively making it suitable for autopilot roll control [3]. In the early days of aircraft system, aircraft required the continuous attention of pilot to fly safely. Mechanically or manually operated flight control systems are the basic method of controlling aircraft. They are widely used in early aircraft and present small aircraft. A conventional flight control system uses a collection of mechanical arrangements to transmit the forces

applied. Increasing in the control surface area became necessary in order to fit all the required mechanical parts. This led to increase the forces required to move those parts along with that the weight and the complexity of mechanical flight control system increased considerably which affected the aircraft performance [10].

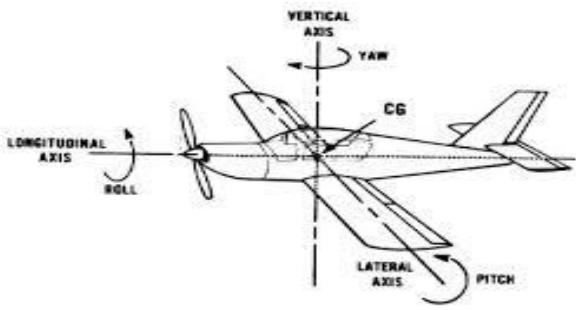

Figure 1: Axes of an aircraft

In the present work, the design of a Proportional-Integral-Derivative(PID) Controller is considered as a valuable approach to study the behaviour of Control Surfaces by considering a General Navion Aircraft model. This is done by obtaining the mathematical model of the considered aircraft for the Longitudinal motion which represents the Pitch moment. The design is implemented using the Model Based programming (SIMULINK) of MATLAB. The gain values of the PID controller is obtained by the automatic tuning tool of the MATLAB i.e the pidtool

Manuscript revised May 13, 2019 and published on June 5, 2019
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doi: 10.32622/ijrat.76S201945

II. Methodology Used

The control system design process is described in the flowchart.

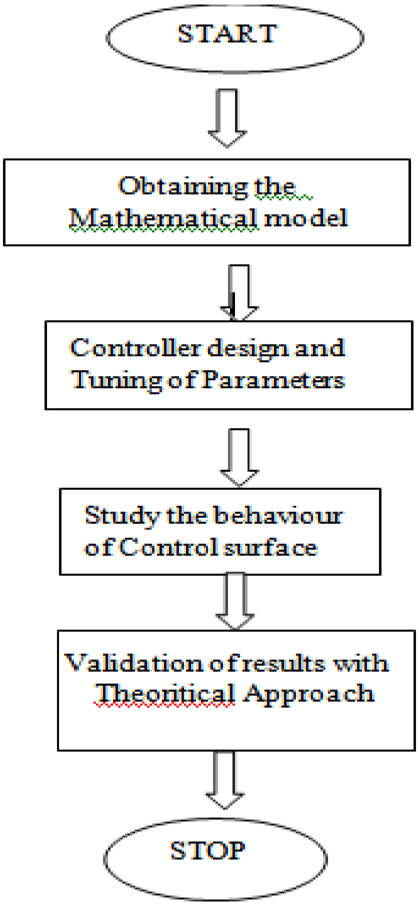

Figure 2: Flow chart for designing PID controller for stable system

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The above flowchart shows the process of how the method is carried out for designing a controller. At first the data required for the designing of a controller is collected and the obtained data is tabulated according to the control system responses. The data obtained is later verified using MATLAB SIMULINK TOOL [4]

III. Problem Formulation

MATHEMATICAL MODELLING

To Obtain the Mathematical Model of the Aircraft(General Navion Aircraft is Considered here) for the longitudinal motion, firstly the Longitudinal Dynamics of the Aircraft model is considered. The longitudinal Dynamics gives the required transfer function in terms input and output considerations. For the Present Study, the variation of Pitch angle w.r.t the elevator deflection is studied. Hence the Input parameter is the Elevator deflation angle and the output parameter is the pitch angle. With the assumed consideration the mathematical model in terms of Transfer function of General Navion Aircraft for short period approximation is obtained as

$$C(s) = \frac{0.1599\,S - 11.538}{S^2 + 3.18S + 3.989}$$

With the unity feedback system is

$$C(s) = \frac{0.1599s - 11{,}538}{s^2 + 3.345S - 7.459}$$

The Mathematical model is analysed in time domain and the time domain specifications obtained are: Maximum Overshoot of 8.9%, Peak Time of 1.45 seconds, Settling Time of 2.4 seconds and a Rise Time of 1.02 seconds

With the above design considerations, the model is implemented using the Model Based Programming approach of MATLAB and the results are simulated. The obtained results are then compared and validated with the theoretical approach.

IV. Results And Discussion

Simulations are performed on the Controller Design for aGeneralNavion Aircraft. The results are as shown in Figure 4 The simulation results are as shown in Figure 4. It can be visualised from the result that the time domain specifications obtained are : The peak overshoot is 8.38%, a rise time of 0.145 seconds, a settling time of 2.35 seconds and the peak time of 1.08 seconds. It can be seen from the results that the designed controller is meeting the design requirement and results are converged with reduced rise time and optimum. settling time

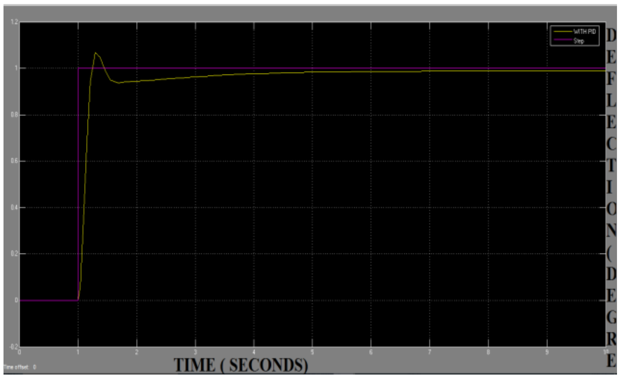

Figure 4: Step response of General Navion aircraft with PID controller

Table 1: Comparison results of theoretical and Simulink modeling

[1]	[2] **Performance parameters of theoretical analysis**	[3] **Performance parameters of simulink analysis**
[4] **RISE TIME**	[5] 1.02 seconds	[6] 0.145 seconds
[7] **SETTLING TIME**	[8] 2.4 seconds	[9] 2.35 seconds
[10] **MAXIMUM**	[11] 8.9%	[12] 8.38%

doi: 10.32622/ijrat.76S201945

OVERSHOOT		
[13] PEAK TIME	[14] 1.45 seconds	[15] 1.08 seconds

V. CONCLUSION

A Proportional- Integral-Derivative(PID) Controller is designed to study the behaviour of Control Surfaces in time domainfor a General Navion Aircraft model using SIMULINK of MATLAB. The focus of the work was mainly on the longitudinal motion of the aircraft i.e for controlling the pitch movement. A peak overshoot of 8.38%, a rise time of 0.145 seconds and a settling time of 2.35 seconds were obtained as time domain specifications . The type of controller designed meets the design requirements and is optimized to achieve system stability.

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