CONTROL AND STABILIZATION OF PITCH AXIS ANGLE IN 3 DOF TITLTROTOR

Mr.R.Dhanasekar¹, Ms.M.Kalaiyarasi², Mr.S.Arunjayakar³, Mr.M.Raghunath⁴, Mr.S.Raghavendra prabhu⁵

1,2, 3Assistant Professor, Bannari Amman Institute of Technology, Department of Electronics and Instrumentation Engineering, Erode, Tamilnadu, India.
4,5 Assistant Professor, Department of Mechatronics, Bannari Amman Institute of Technology, India.
dhanasekar1693@gmail.com, kalaiyarasim@bitsathy.ac.in, arunjayakars@bitsathy.ac.in, ragueee19@gmail.com, raghavendaraprabhu@bitsathy.ac.in

ABSTRACT - Tiltrotor system is used in army for security purpose and mission attack. This system is affect due to environment conditions such as wind flow, rain and low atmospheric pressure, the system becomes unbalanced in working conditions. In recent days new control technique called fractional order PID have a conspicuous growth in the field of controller design for controlling the various linear and nonlinear system applications. The fractional order PID controller used in tiltrotor model, improves the system performance compared with other controllers. The proposed work deals with the Pitch axis control of tiltrotor system using FOPID controller and also performance has been compared with PID controller, with different tuning methods. The FOPID controller provide more flexibility in designing a controller than using PID controller due to selection of tuning parameters. FOPID and PID controller has been designed for pitch axis control, the performance characteristics of the system has been compared and analyzed by using MATLAB simulation.

Keywords : Tiltrotor – FOPID - Pitch axis - PID Controller.

I. INTRODUCTION

1.1 BENCH TOP TILTROTOR MODEL

Tiltrotor framework is made out of the base, utilized equalization, adjusting squares, propellers and some different parts. Equalization post to base as its support, and the pitching. Propeller and the equalization blocks were introduced at the two finishes of a parity bar. The propeller rotational lift, turning an equalization bar around the support so pitching moves, utilizing two Propeller speed contrast, turning a parity bar along the support to do rotational development. Parity the two shafts introduced encoder, used to quantify the turn hub, pitch hub point, in the two propeller associating pole introduced an encoder, which is utilized to gauge upset hub edge as appeared in figure 1.1.. Two propellers utilizing brushless DC engines, give the catalyst to the propeller. By modifying the equalization bar introduced in the side of the parity squares to diminish propeller engine yield. All electrical signs to and from the body are communicated by means of slip ring in this way wiping out the chance of tangled wires and decreasing the measure of contact and stacking about the moving pivot. Arrangement of the exploratory direction on the intention is to advise clients how to plan a regulator, to control the helicopter as per the ideal point and speed of development.
1.2 PID CONTROLLER

Proportional integral derivative controller (PID controller) is a control loop feedback mechanism (controller) commonly used in industrial control systems. A PID controller continuously calculates an error value as the difference between a measured process variable and a desired set point. The PID control scheme is named after its three correcting terms, whose sum constitutes the manipulated variable (MV). PID controllers, when used alone, can give poor performance when the PID loop gains must be reduced so that the control system does not overshoot, oscillate or hunt about the control set point value. They also have difficulties in the presence of non-linearity, may trade-off regulation versus response time, do not react to changing process behavior (say, the process changes after it has warmed up), and have lag in responding to large disturbances.

1.3 FOPID CONTROLLER

A fragmentary request PID regulator is spoken to as $[\text{PI}]^{\lambda} D^\mu$. It permits us to alter subordinate and indispensable request notwithstanding the corresponding, essential and subsidiary constants where the estimations of $\lambda$ and $\mu$ lie somewhere in the range of 0 and 1. FOPID regulator improves the quality and power of the framework than the ordinary PID regulator. This gives additional opportunity to work regarding two handles as,

- Order of differentiation
- Order of integration

This likewise gives greater adaptability to better the dynamical properties of the control framework. The fragmentary request regulator delights great heartiness. The power of partial regulators gets more featured within the sight of a non-linear actuator.

II. MATHEMATICAL MODELING FOR TILTROTOR SYSTEM

It is made out of the base, utilized equalization, adjusting squares, propellers and some different segments. Equalization presents on base as its support, and the pitching. Propeller and the equalization blocks were introduced at the two closures of a parity bar. The propeller rotational lift, turning a parity bar around the support so pitching moves, utilizing two propeller speed contrast, turning an equalization bar along the support to do rotational development. Parity the two posts introduced encoder, used to gauge the pivot hub, pitch hub point, in the two propeller interfacing bar introduced an encoder, which is utilized to quantify toppled hub edge. Two propellers, utilizing brushless DC engines, give the driving force to the propeller. By, changing the parity pole introduced in the side of the parity squares to diminish propeller engine yield.
### 2.1 PITCH AXIS

Expecting the move pivot zero, at that point the pitching hub force by two propeller engine lift the F1 and F2 as appeared in figure 2.1. Accordingly the pitch propeller pivot all out lift \( F_h = F1 + F2 \). At the point when the lift \( F_h \) is more prominent than the gravity \( G \) helicopter rise. Rather the helicopter dropped. The pitch hub model for tiltrotor is indicated Fig.2. Presently, expecting zero move hub, the differential condition is,

\[
J_p \ddot{\theta} = M_m \text{diff (udiff)} + Mg\dot{\theta} + M_{cor}\theta \quad \text{------------------------ (1)}
\]

Gravitational force and Coriolis force should be zero in motion state,

\[
J_p \ddot{\theta} = M_m \text{diff (udiff)} \quad \text{------------------------ (2)}
\]

Where,

- \( J_p \) is the moment of inertia
- \( M_m \text{diff} \) is the momentums caused by the motor
- \( u\text{diff} \) is the difference between front motor and back motor
- \( M_{cor} \) is the Coriolis force

\[
J_p \dot{\theta} = W_u\text{diff} \quad \text{------------------------ (3)}
\]

| S.No | Tuning Method | \( K_p \) | \( K_i \) | \( K_d \) | \( \lambda \) | \( \mu \) |
|------|---------------|----------|----------|----------|----------|----------|
| 1    | Z-N           | 0.392    | 1.177    | 0.72     | 0.6      | 0.5      |
| 2    | T-L           | 0.556    | 0.416    | 0.29     | 0.6      | 0.5      |

Laplace transform apply in equation (3)

\[
\frac{d\dot{\theta}(s)}{d\theta(s)} = \frac{udiff}{J_p s^2} \quad \text{------------------------ (4)}
\]

By substituting the below values on the pitch axis transfer function in equation (4),

\( U\text{diff} = 1.5N_{j_p} \cdot 0.03kg/m^2 \) At 45° motion position,
\[
\frac{d\theta h(s)}{d\theta w(s)} = \frac{50}{s^2} \quad \text{------------------------ (5)}
\]

U diff=2.5N,j\(\rho\)=0.03kg/m²: At 70° motion position,
\[
\frac{d\theta h(s)}{d\theta w(s)} = \frac{83.3}{s^2} \quad \text{-------------------------- (6)}
\]

### III CONTROLLER DESIGN FOR TILTROTOR MODEL

#### 3.1 DESIGN OF CONVENTIONAL PID CONTROLLER

The design of the conventional PID controller is in need the exact values of the controller tuning parameters \(K_p, K_i, K_d\) in accordance with the system transfer function.

| Tuning methods | Tuning parameters |
|---------------|-------------------|
|               | \(K_p\) | \(K_i\) | \(K_d\) |
| Z-N           | 0.392  | 1.1    | 4.722   |
| T-L           | 0.556  | 0.4    | 5.295   |

#### 3.2 DESIGN OF FOPID CONTROLLER

The design of FOPID controller is in finding the five controller tuning parameters \(K_p, K_i, K_d, \lambda, \mu\).

### IV RESULTS AND DISCUSSION

The system model which consist of controller and the feedback loop for control the input flow in order to reduce the error by adjusting the tuning parameters using Ziegler–Nichols and Tyreus luyben tuning.

Figure 4.1 Closed Loop Response of Pitch Axis
Table 1. Closed Loop of PID Controller for Pitch Axis

| Overshoot (%) | Rise time (seconds) | Settling time (seconds) |
|---------------|---------------------|-------------------------|
| 60            | 0.75                | 2.56                    |

From the Figure 4.1 it is observed that angle for set point of 45 degrees, the PID controller and FOPID controller responses with settling time of 2.56 seconds. The Table 1 shows the closed loop of PID controller and FOPID controller for pitch axis. Also while comparing with open loop system, the PID and FOPID controller obtained the desired set point.

Figure 4.2. Response of Closed Loop for Pitch Axis

Table 2. Closed Loop with Disturbances in Pitch Axis

| Overshoot (%) | Rise time (seconds) | Settling time (seconds) |
|---------------|---------------------|-------------------------|
| 60            | 0.75                | 2.56                    |

From the Figure 4.2 it is observed that angle for set point of 45 degrees, the PID controller and FOPID controller responses with settling time of 2.56 seconds. The Table 2 shows the closed loop of PID controller and FOPID controller for pitch axis. Also while comparing with open loop system, the PID and FOPID controller obtained the desired set point.

Figure 4.3. Response for closed loop of PID and FOPID Controller
Table.3. Closed Loop of PID and FOPID Controller for Pitch axis

| Overshoot (%) | Rise time (sec) | Settling time (seconds) |
|---------------|-----------------|-------------------------|
| 40            | 0.5             | 39.4                    |

From this Figure.4.3 it is observed that angle for set point of 70 degrees, FOPID and PID controller response are settling time of 39.4 seconds and over shoot of -. The Table.3 shows the closed loop of FOPID and PID controller for pitch axis. While FOPID controller is compared with PID controller, the FOPID controller overshoot is reduced.

Fig.4.4 Response for Closed Loop with Disturbances in Tiltrotor Pitch Axis

Table.4. Closed Loop with Disturbances in Tiltrotor Pitch Axis

| Overshoot (%) | Rise time(seconds) | Settling time(seconds) |
|---------------|--------------------|------------------------|
| 40            | 0.2                | 2.56                   |

From the Figure.4.4 it is observed that angle for set point of 70 degrees, the PID controller and FOPID controller responses with settling time of 2.56 seconds. The Table.4 shows the closed loop of PID and FOPID controller for pitch axis.

V. CONCLUSION AND FUTURE SCOPE

The tiltrotor bench top model is used to analyze with PID and FOPID controller. Mathematical model of pitch axis is derived and analyzed using different tuning methods. The control of pitch angle for 3 DOF tiltrotor can be done using some other advanced controller to improve the accuracy.

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