PITCH CONTROLLER FOR AEROPLANE USING PID METHOD

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MAY 2009

"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronic and Drive)"

Signature : ....

Supervisor's Name : Hyreil Anuar bin Kasdirin

Date : 13 / 5 / 2009.

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Fakulti Kejuruteraan Elektrik
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MAY 2009

"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references."

Signature : ....

Name : Ahmad Syazwan bin Che Muhamad

Date : 13 / 5 / 2009

For my beloved father and mother
Che Muhamad bin Haji Awang and Esah bt Abdul Rahman
In appreciation of supported and understanding.

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ABSTRACT

The purpose of this project is about to design a Pitch controller for aeroplane control using PID control algorithms. In this project, pitch controller are generally controlled by Proportional-Integral-Derivative (PID) controllers. The PID controller method was implemented into the pitch controller in this project. A PID controller is a generic control loop feedback mechanism widely used in control systems. The PID controller calculation involves three separate parameters; the proportional, the integral and derivatives values. The proportional value determines the reaction to the current error, the integral determines the reaction based on the sum of recent errors and derivative determines the reaction to the rate at which the error has been changing. The weighted sum of these three actions is outputted to a control the pitch rate of plane. By tuning the three constants in the PID controller algorithm the PID can provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the set point and the degree of system oscillation. Finally, the conclusion and suggestion to improve this project is state for the future study

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CHAPTER I

INTRODUCTION

1.1 Overview

When designing an aeroplane, there are a tremendous amount of issues that a design team needs to be concerned with. The wide variety of disciplines that a typical aerospace engineering student is introduced to is testimony of this fact. Among a wide variety of other important factors, an aeroplane stability and control is a key design parameter must be met.

Often times an aeroplane can be designed in such a way as to be inherently stable. That is, a perturbation in the lateral or longitudinal dynamics of the aeroplane will not cause undesired effects.

However, often times other issues will call for an aeroplane to be designed with inherently unstable dynamics. High speed, high performance aeroplane often falls into this category. Stability is still necessary, though. Because the natural dynamics of the system is unstable, automatic control must be used in order to bring about stability for the system.

The present invention relates to design a pitch controller for an aeroplane by using PID method. This project will analyze and simulate the model aeroplane using MATLAB environment. Then we can determine how the PID controller can be use to produce the required output.. It is appropriate to consider the state of the art in PID control as well as new developments in this control approach. It is also suitable for use in a control system where the transfer function of the plant has not been completely defined. It is very important matter to know mathematical model for tuning the PID parameter. The PID equation is:

$$\mathbf{U = Kp.e + Ki \int e.dt + Kd(de/dt)} \qquad \textbf{(1.1)}$$

1.2 Projects Objective

The main core of this project is to design a pitch controller for an aeroplane. This system will be able to control the aeroplane pitch angle. The specific objective can be described as below:

- To understand the design of PID as a controller for the pitch control.
- To understand and develop the basic of PID methodology.
- To analyze the result from the design and test using PID algorithm on aeroplane model using MATLAB 7.0 environment.

1.3 Project Scope

In order to achieve the objective of the project, there are several scopes that had been outlined. The scope of this project is focusing on software and analysis. The main areas are being identified those needs to be worked out are:

1. To study the theory of PID controller
2. To study the capability of the controller in non-linear systems
3. To design the PID controller for aeroplane model

1.4 Problem Statement

There are many types of controller that use to improve the capability and stability of the aeroplane pitch angle. PID is an intelligent controller that can control system especially for non-linear system because of its simplicity and reduced development cycle. This controller also much easier to implement in the system to get the desired result.

But remember, as usual PID control aim are to get no overshoot, no steady state error, minimum settling time and minimum rising time. All of this requirement must to be consider when implement to the pitch controller.

1.5 Final Report Arrangement

This final project report will be discussed by chapter. Chapter 1 discuss about the introductions of this project. Literature Review will be discussed in Chapter 2 that detail on the theory and reference project, follow by Methodology in Chapter 3 that detail on this project's flow chart and work plan. Result from this project will be detail in Chapter 4 meanwhile discussion, conclusion and recommendation in Chapter 5.

CHAPTER II

LITERATURE REVIEW

2.1 Overview

This chapter will discuss about the literature review and theory for the project. In this chapter there are projects from other research that related to this project and used different method of controlling the position system.

2.2 Aircraft pitch control using an adaptive controller with projection base disturbance rejection and drift avoidance.

From the article of David Fiedman, aircraft pitch controller is designed based on initial adaptive controller. Classical control methods require a near complete understanding of how the plants work to drive the output to a desired state. For many system these system can be measured accurately. An airplane pitch controller is designed to change the pitch of an aircraft using deflection angle of elevators.

Their control system's aims are;

1) Overshoot < 10%
2) Rise time < 5s
3) Settling time < 10s
4) Steady state error < 2%

An adaptive controller is added to their pitch controller system so that deviation from expected dynamic can be adjusted. The gains are changed by following adaptive laws:

$$\dot{k}_x = -\Gamma_x x(t) e^T(t) Pbsign(\lambda)$$
$$\dot{k}_r = -\gamma_r(t) e^T(t) Pbsign(\lambda) \qquad \textbf{(2.1)}$$

Where gammas are the gains, e is the error between the model and the plant, λ is constant multiplier on b and P solves the algebraic ricatti equation for some choice of matrix Q.

These gains then added back into the plant as:

$$u = k_x^T(x)(t) + k_r(t)r(t) \qquad \textbf{(2.2)}$$

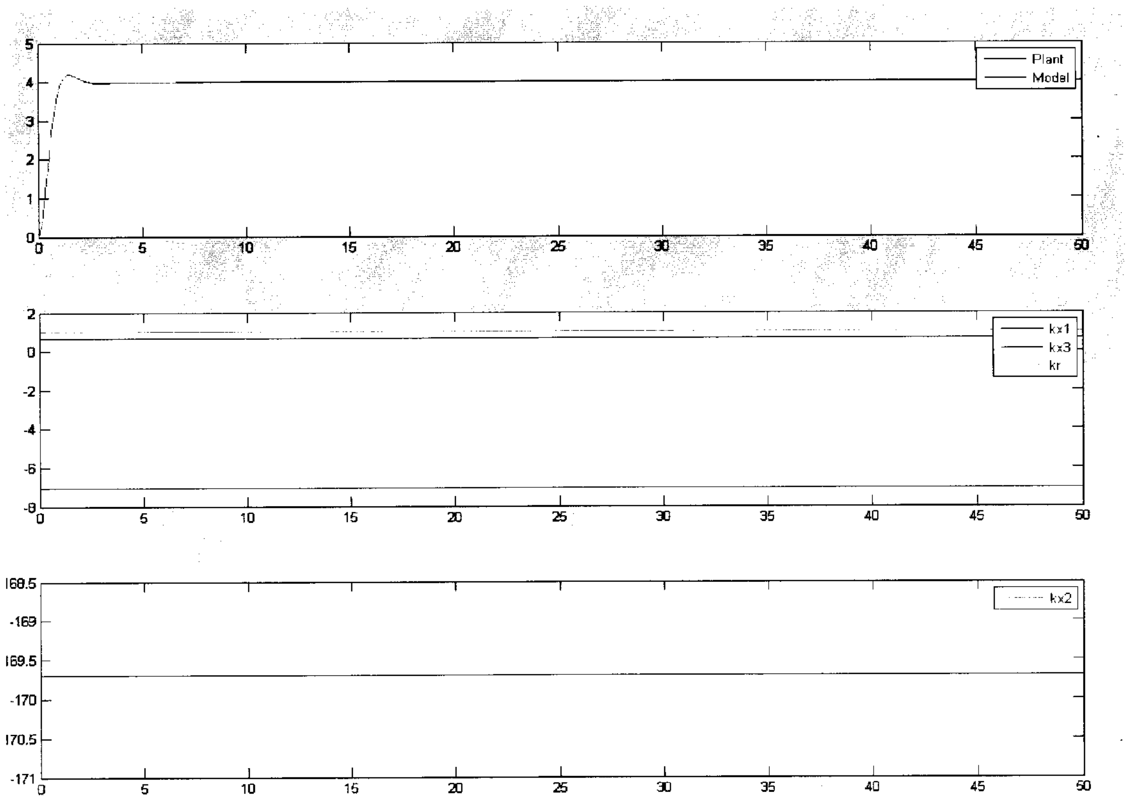

Figure 2.1: Output without any adaptation using unmodified dynamics.

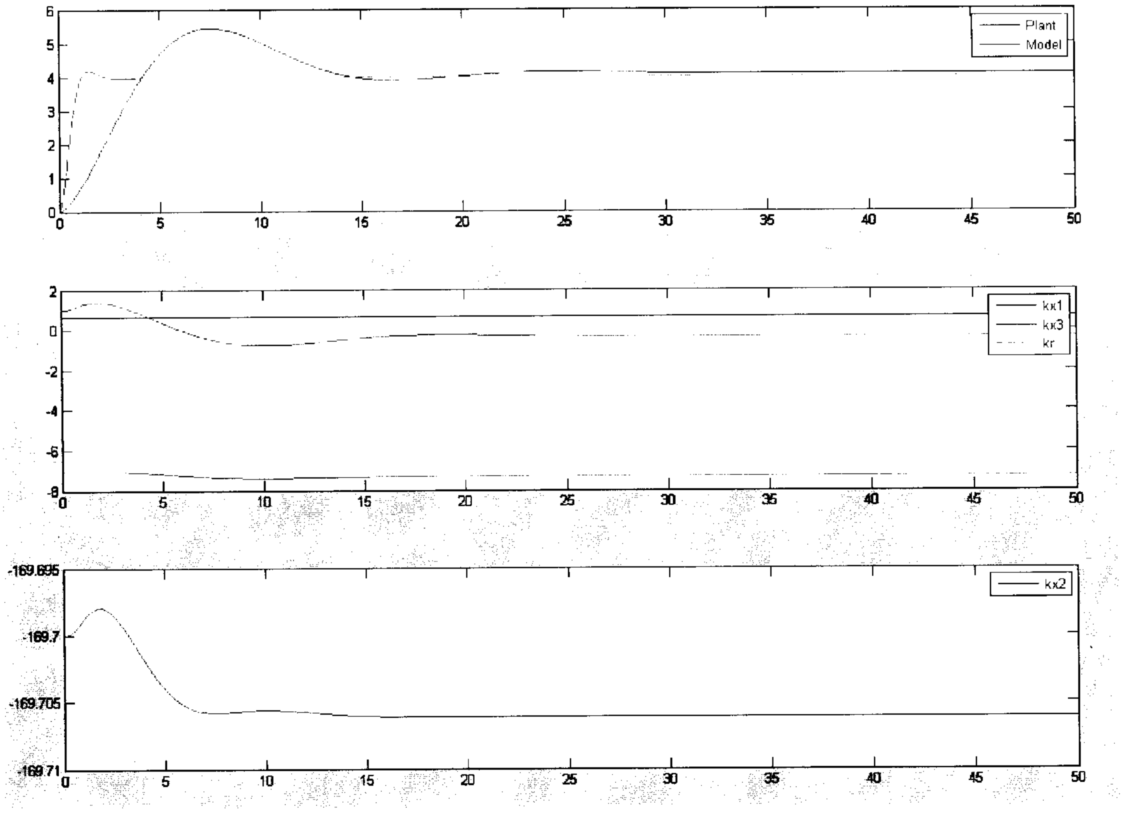

Figure 2.2: Output with adaptation using unmodified dynamics.

2.3 Theory of PID controller

Firstly, it is important to understand the basic of the PID concept. Every term has its own function into the system. The controller will give a signal to the output according to the user. Using the PID concept will ensure the precise output into the system and consists a feedback in the system to provide precise output. Feedback is function to sent actual value of the output to the differential amplifier

A proportional-integral-derivative controller (PID controller) is a generic control loop feedback mechanism widely used in industrial control systems. A PID controller attempts to correct the error between a measured process variable and a desired set point by calculating and then outputting a corrective action that can adjust the process accordingly, based upon three parameters.

The PID controller calculation involves three separate parameters; the Proportional, the Integral and Derivative values. The proportional value determines the reaction to the current error, the integral determines the reaction based on recent errors and the derivative determines the reaction based on the rate by which the error has been changing. The weighted sum of these three actions is outputted to a control element such as the position of a control valve or power into a heating element.

By "tuning" the three constants in the PID controller algorithm the PID can provide individualized control specific to process requirements including error responsiveness, overshoot of set point and system oscillation. Note that the general nature of PID control does not guarantee optimal control of the system.

Some applications may require only using one or two modes (by setting undesired control values to zero) to provide the appropriate system control. A PID controller will be called a PI, PD, P or I controller in the absence of respective control actions. PI controllers are particularly common, since derivative action is very sensitive to measurement noise, and the absence of an integral value prevents the system from ever reaching its target value due to control action.

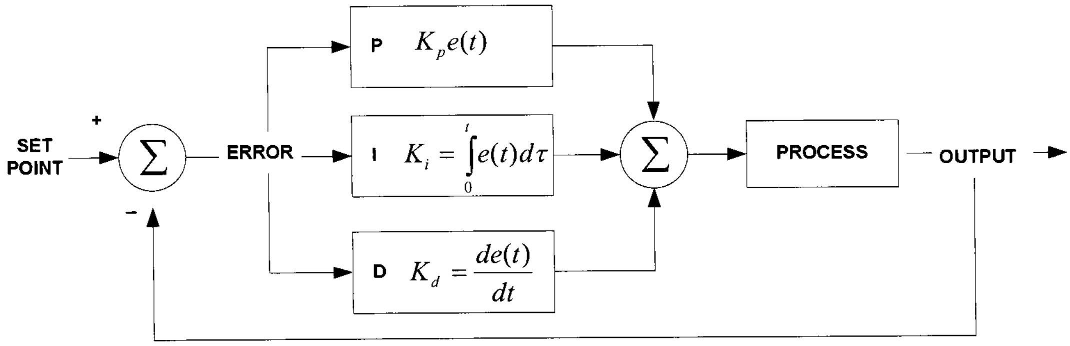

Figure 2.3: Block Diagram of PID

2.3.1 Proportional term

The proportional term responds to a change in the process variable proportional to the current measured error value. The proportional response can be adjusted by multiplying

the error by a constant Kp, called the proportional gain or proportional sensitivity. The gain is also frequently expressed as a percentage of the proportional band. The proportional term is written as:

$$P_{out} = K_p e(t) \qquad \textbf{(2.4)}$$

- *Pout*: Output Signal
- K_p: Proportional Gain
- *e*: Error equal to (set point value - process variable)

A high gain results in a large response to a small error, a more sensitive system (Also called a narrow proportional band). The setting proportional gain too high, the system can become unstable. In contrast, a small gain results in a small response to a large error, and less sensitive system (Also called a wide proportional band), which is undesirable as the control action may be insufficient to respond to system disturbances.

Finally pure proportional control will never theoretically settle at its target value, but will rather approach the target with a steady state error that is a function of the proportional gain, this is known as a steady state error.

2.3.2 Integral term

The contribution from the integral term is proportional to the past and current values and duration of the error signal. The integral term algorithm calculates the accumulated proportional offset over time that should have been corrected previously (finding the offset's integral). While this will force the signal to approach the set point quicker than a proportional controller alone and eliminate steady state error, it may also contribute to system instability as the controller will always be responding to past values. This instability causes the process to overshoot the set point since the integral value will continue to be added to the output value, even after the process variable has reached the desired set point.

The responsiveness of the integral function can be calibrated to the specific process by adjusting the constant Ti, called the integral time.

The equation is written as:

$$\mathbf{I}_{out} = K_i \int_0^t e(t) d\tau \qquad \textbf{(2.5)}$$

- *Iout*: Output Signal
- K_i: Integral Time
- *e*: Error equal to (set point value - process variable)

Although mathematically the integral starts at t = 0, it is possible to modify the integral to such that it does not "record" all historical values of the error signal. There are many possible schemes for performing such modification, such as windowing the signal or applying a decay term to the integral value itself.

2.3.3 Derivative term

The derivative term provides a braking action to the controller response as the process variable approaches the set point. To accomplish this the process error is predicted at a time in the future Td, calculated by analyzing the slope of error vs. time (i.e. the rate of change of error, which is its first derivative with respect to time) and adding the anticipated proportional term to the current correction.

Derivative control is used to reduce the magnitude of the overshoot produced by the integral component, but the controller will be a bit slower to reach the set point initially. As differentiation of a signal amplifies the noise levels, this mode of control is highly sensitive to noise in the error term, and can cause a noisy controlled process to become unstable.

By adjusting the constant, Td, the derivative time, the braking action sensitivity is controlled.

The derivative term is written as:

$$D_{out} = K_d \frac{de}{dt} \qquad \textbf{(2.6)}$$

- *Dout*: Output Signal
- K_d: Derivative Time
- *e*: Error equal to (set point value – process variable)

2.3.4 Tuning the PID controller

Selecting optimal values for the P and D parameters of a closed loop control system is usually an iterative process. This process is called PID tuning. Before tuning begins; verify that all components of the control loop operate correctly. Test input processing tasks to verify that the measurements of system output are sampled correctly. Test output procedures to verify that the control output is correctly scaled. Verify that the PID controller processes the sampled input and produces an output sequence which is consistent with the input. If possible, verify that the system responds correctly to its control input