ELECTRONIC THROTTLE BODY TUNING USING MODEL REFERENCE ADAPTIVE CONTROL PID

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This report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering (Automotive)

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DECLARATION

I declare that this project report entitled “Electronic Throttle Body Tuning Using Model Reference Adaptive Control PID” is the result of my own work except as cited in the references

Signature : .....

Name : .....

Date : .....

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Automotive).

Signature :. .....

Name of Supervisor : .....

Date : .....

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DEDICATION

Dedicated, in thankful appreiation for support, encourangement and understanding to my beloved mother, father, sister, brothers and friends.

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ABSTRACT

The electronic throttle body (ETB) have been widely used in many kind of vehicles recently. Even thought, the ETB is one of the new technology it still has some defect in it. The non-linearity that lies inside the system such as stick-flip friction, gear backlash and the discontinuous nonlinear of the spring that make the valve plate to return to its original position affect the performance of the ETB. In this project, the ETB will be tuned using Model Reference Adaptive Control (MRAC) PID controller. The project is start by creating an ETB model by using the Matlab/Simulink software. Then, PID controller is tune to gain the proportional gain, Kp, integral gain, Ki and derivative gain, Kd. Those gain will be used in the MRAC. Then, the project is continuing by applying the MRAC PID to the ETB Model. Next is the result for the MRAC PID is compare to the conventional PID. Lastly, the simulation is tested on different angle.

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ABSTRAK

Sejak kebelakangan ini, Badan Pendikit Elektronik (ETB) telah digunakan secara meluas dalam pelbagai jenis kenderaan. Walaupun ETB adalah salah satu teknologi yang masig baru, namun masih terdapat beberapa kecacatan dalam system tersebut. Ketidaklinearan yang terletak di dalam sistem seperti geseran 'stick-flip', tindak balas gear dan ketidaklinearan yang tidak berterusan spring yang membuatkan plat injap untuk kembali kepada kedudukan asalnya telah menjejaskn prestasi ETB. Dalam projek ini, ETB akan ditala menggunakan Model Rujukan Adaptive Control (MRAC) PID. Projek ini akan dimulakan dengan membina model ETB menggunakan perisian Matlab/Simulink. Kemudiannya, PID akan ditala untuk mendapatkan proportional gain, Kp, integral gain, Ki and derivative gain, Kd. Gain tersebut akan digunakan dalam MRAC. Kemudiannya projek ini di teruskan dengan mengaplikasikan MRAC PID didalam model ETB. Seterusnya, hasil daripada MRAC PID akan dibandingkan dengan PID konvensional. Akhir sekali, simulasi diuji pada sudut yang berbeza.

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LIST OF ABBREVIATION

EEV	Earth Efficiency Vehicles
ETB	Electronic Throttle Body
PID	Proportional Integral Derivative
MRAC	Model References Adaptive Control

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CHAPTER 1

INTRODUCTION

1.1 Background Study

During this area of globalization, the automotive sector has been one of the major contributor to the nation income. With Proton and Perodua lining up our local automotive manufacturer with some other global manufacturer such Toyota, Honda, Ford and BMW, our automotive sector look quite promising in the next few years. Nowadays, all of the car manufacturer are targeting to build an earth efficiency vehicle (EEV) that can improve the driveability, fuel economy and the emission of the vehicle (Pavković et al. 2006). One way to achieve these is by using the Electronic Throttle.

Generally, the conventional vehicles use the mechanical parts that link the gas pedal to the throttle plate. The gas pedal works when the driver is pushing on the pedal. As the pedal is pushing, there is a pivot that pulling a throttle wire that connected to the throttle linkage. The throttle linkage will open and close the valve plate in the throttle body that allows certain amount of air into the engine. But there will be a system of sensors that sense more amount of the air coming to the engine, the more fuel will be injected into the engine. Nowadays, as the technology keeps rising, the researchers found a way to control electronically the amount of the air fuel ratio that been supply to the combustion chamber during the combustion process. The Electronic control system controlled this ratio by changing the opening angle of the valve plate according to how much the driver is pushing the gas pedal (Pan et al. 2008).

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Figure 1: The Throttle Body.

Besides that, the Electronic Throttle Body also can perform as a mechanism that improve significantly the engine and vehicles performance. There is a research that shows the driver can choose the powertrain responsiveness to match his or her desire (Mckay et al. 2000). By choose a certain mode, the electronic throttle body or control will adjust the gain or sensitivity of the accelerator pedal in response to the driver input selection. To choose the mode, the driver only need to push a certain button and the rest will be up to electronic throttle control to fulfil those requirements such as the driving condition and the driver mood. Lately, there are three kinds of that is available at the market which are normal mode, power mode and winter mode. There is still more mode to add to the vehicle but those three mode are currently commonly being used.

In this research, PID Model References Adaptive Control. controller using a Matlab Simulink is more favourable than the conventional passive method(Rao 2014). Matlab is a high-performance language for technical computing. It integrates computing, programing and visualizing in an easy-to-use environment where problem and solutions are expressed in familiar mathematical notation. For Simulink, it is a program that integrated with Matlab. It is very useful when designing a dynamic system and make a performance test. Simulink use some block diagram to represent a dynamic system (Mathworks 2014). So, modelling an electronic throttle body using this software, it can give us advantages such as a simulation, optimization and data analysis.

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For Model Reference Adaptive Control(MRAC), it is a control system that make the plant to be as close as possible to the model references. The input or the control parameter of the plant are being adjusted automatically for time to time(R. Isermann, K.-H. Lachmann and Matko 1992). As the parameter of the plant continuously being change, the output of the system will be based on the desired response that have being set for the references model. The existence of the MRAC controller will compensate the disturbance that have been create by the nonlinearities of the Electronic Throttle Body. Adaptive control also very good at tracking the performance of the system.

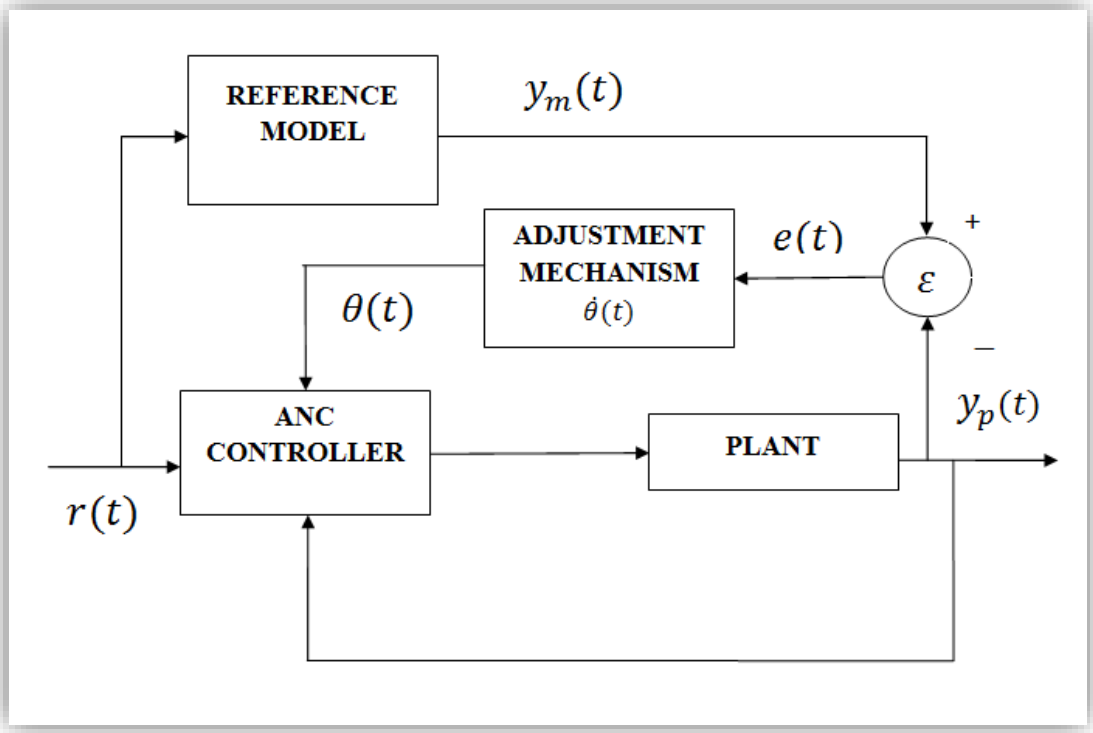

Figure 2: The block diagram of the Model References Adaptive Control.

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1.2 Problem Statement

Electronic throttle body is one of essential part that needs in current vehicles so that it can adjust the ratio between the air and fuel that enter the combustion chamber. The problem is that the electric throttle body have some non-linearity such as stick-flip friction, backlash that occurs between the gear and the discontinuous nonlinear of the spring that use to return the valve plate to its initial position. This non-linearity causes the disturbance that can affect the performance of the electronic throttle body.

So, in order to overcome this problem, a proper controller will be needed to compensate the disturbance by the non-linearity. The propose controller that will be used in this project is Model References Adaptive Control (MRAC) PID. To apply the controller, a model of Electronic Throttle Body will be model by using Matlab/SIMULINK. Then, MRAC will be applied in the ETB model.

1.3 Aim and Objective

The aim of this research project is to tuning the Electronic Throttle Body using Model References Adaptive Control PID

The aim and the research objective of the thesis are:

- To develop an Electronic Throttle Body(ETB) model in Matlab Simulink.
- To apply Model Reference Adaptive Control PID controller to obtain the desired throttle angle.
- To compare the result with conventional PID.

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1.4 Scope of Project

The scope of this project are:

1. Study about the throttle body on how to control the disturbance created by the non-linearity of the system.
2. This project only focus on simulation only.
3. The simulation will be perform using Matlab (Simulink) software.
4. Model the ETB provide by (Pan et al. 2008) by using matlab/simulink
5. Apply the Model reference adaptive control PID to the ETB model.
6. Compare the result for conventional PID with MRAC PID.
7. Do various simulation for different throttle opening angle such as 30^o, 45^o, 60^o, 75^o and 90^o.

1.5 Thesis Outline

The First chapter is an introduction part which discusses briefly on the background, problem statement, aim and objective of the project. Besides that, this chapter will briefly mention about the outline of the project.

Chapter Two will discuss about the literature review. All the concept and operation that related to the Electronic Throttle Body will be discus. The study about the controller and the method of the control will be discus.

Next, chapter Three will discuss about the method used to carry out this project. The steps to complete this project also will be discussed in this chapter, including the tuning method and the simulation. The step to model the plant and the controller also being discuss in this chapter.

Chapter Four will mention about the result and discussion of the performance. The data from the simulation will be graphed. The comparison between the MRAC PID and the conventional PID is discussed.

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The last chapter will be the conclusion. All other future suggestion and recommendation will be mentioned in this chapter. Hopefully all the opinions and ideas will provide benefits for the future studies.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the relevant literature review in application related to research of electronic throttle body, type of controller, type of manual tuning method, automatic tuning method and modelling

2.2 Throttle Body

For every vehicle, to control the speed either to increase the speed or to decrease it is very importing characteristic that should be include in the vehicles. One way to control the speed is by controlling the air fuel ratio that enter the combustion chamber. So, throttle body is the one who control the ratio. The throttle body works by adjusting the valve plate that place inside the throttle body(Pan et al. 2008). When the acceleration pedal is pushed, a mechanical linkage that link the pedal and the valve plate will pull a spring that open the throttle angle(Panzani et al. 2011)(Rossi et al. 2000). As the valve is open, it will allow the air and fuel to enter the combustion chamber.

Figure 3: The Throttle Body.

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With now advance technology, the mechanical linkage now not directly connected to the gas pedal anymore. The existence of the Electronic Throttle Body (ETB) is widely used in modern car now days. It is because of the reliability of the throttle body itself. For ETB, the gas pedal not connected to the throttle body but to the sensor. The sensor will sense the position of the gas pedal and will send the Engine Control Unit (ECU)(Mckay et al. 2000). The function of ETU is to determine the opening angle of the valve. By taking others input parameter from the engine such as the slop of the road, road condition, and the driver behaviour, the control unit will determine the best opening angle of the valve. The advantage of using ETB is the fuel efficiency, a comfortable drive experience, and less emission.

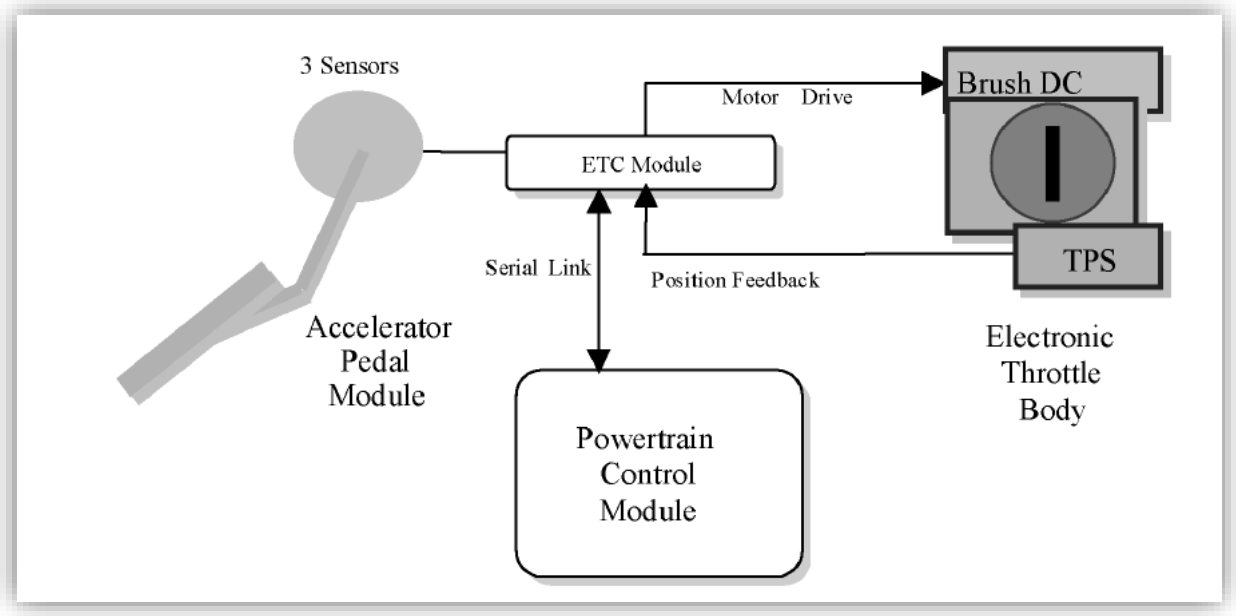

Figure 4: The Electronic Throttle Body schematic diagram.

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2.3 Gear Backlash

One of the problem that occurs in Throttle Body is that there is lies the backlash of the gear that need to turn the valve plate. The existence of the gearing backlash has cause the disturbance of the Throttle body system and may have affected its performance. Gear backlash exist because of the gap between the gear tooth(Engineering 1996). These phenomena are common in servomechanism especially in mechanical system that involve the gear-driven system.

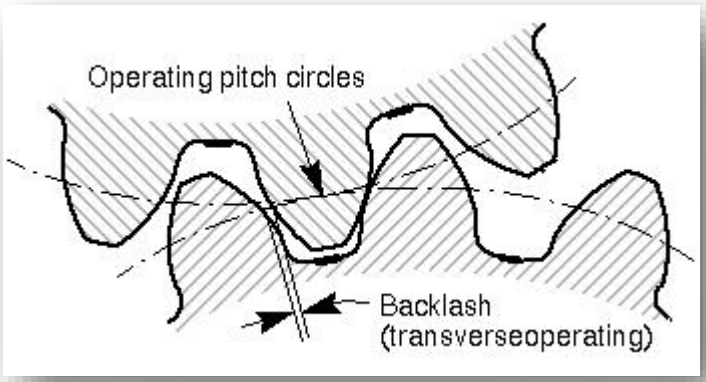

Figure 5: The backlash of the gear.

Backlash is not necessarily a bad thing for the gearing system. With a certain amount of the backlash, the system can operate in an optimum performance but once the amount of the backlash greater that the maximum allowed, it can cause the positioning error and make the system to become unstable. To eliminate the backlash nonlinearity is quite challenging itself(Shi & Zuo 2015). It is because as long the gear system is being used, there will be the backlash nonlinearity. As for the research, the propose control system which is the Model References Adaptive Control will compensate the disturbance that have been created by the backlash nonlinearity.

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2.4 Mathematical Modelling

Modelling is the process of identifying the physical dynamic effects to be considered in analysing the system. The modelling can involve many mathematical equation such as ordinary differential equation (ODEs), partial differential equations (PDEs), differential algebraic equations (DAEs) and ODEs interfaced with discrete-time algorithms (DTAs)(Taylor 2001). The purpose of the mathematical modelling is to predict the response of the system before applied into the real system. Actually this project is about modelling a nonlinear system. A nonlinear system is a system in which the output of the system is vary within the time and not directly proportional to the input (Heij & van Schagen 2007). The performance of the Electronic Throttle Body will depend on the efficiency of the control system and the dynamic model of the system. The mathematical modelling of the Electronic Throttle body will be discussed in Chapter 3.

2.5 PID Controller

PID is consider as the best controller in the control system family. PID controller is a short form for Proportional-Derivative-Integral control. A controller is to control a process so that the resulting control stem will reliable and safely achieved high-performance operation(Passino, Kevin M. Yurkovich 1998). Besides that, PID also is a feedback mechanism which is used in a control system. A feedback control means that the controller will uses the information from the measurement of the error. The basic how PID works is by reading an input sensor and then compute the desired output by calculating proportional, integral and derivative responses. Next, sum all three responses and compute the output. There is two type of feedback control which is positive feedback and negative feedback. Positive feedback is used to increase the input value while the negative feedback does the opposite which is down size of the input. Each of the response have different role.

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