

PERFORMANCE OF PID CONTROLLER FOR ENGINE SPEED CONTROLLER
USING CVT

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Report submitted in fulfilment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2010

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I declare that this thesis entitled "Performance of PID Controller for Engine Speed Controller Using CVT" is the result of my own research except as cited in references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ACKNOWLEDGEMENT

In preparing this thesis, I was contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my supervisor, Dr. Sugeng Ariyono, for encouragement, guidance, critics and friendship. Without his continued support and interest, this thesis would not have been the same as present here. I would like to give my sincere appreciation to all my friends and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. Finally to all my family members where without them I would not be here.

ABSTRACT

This project is a simulation and experimental investigation into the development of PID controller using MATLAB SIMULINK software. The simulation development of the PID controller with the mathematical model of DC motor is done using Ziegler-Nichols method and trial and error method. The PID parameters are to be tested with an actual motor also with the PID controller in MATLAB/SIMULINK software. In order to implement the PID controller from the software to the actual DC motor data acquisition is used. From the simulation and the experiment, the result performance of the PID controller is compared in term of response and the assessment is presented. CVT transmission firstly designed using the Solid Work software to know the mechanical system and the dimension of this transmission. Then, the mathematical calculation is done to know the criteria DC Motor to be selected and the exact rotation of the motor as primary source to the transmission. The motor must be capable to produce 4.14N.m or more of torque in order to mechanism to function perfectly until it reach it limit.the DC motor should rotate only in 16.12rad or 2.57 rotation. Therefore PID controller are used to achieve this value in the simulation. After using the trial and error metod in order to decided the exact value for costant value of $K_p=15$, $K_i=25$ and $K_d=0.15$ in PID controller system to ensure the DC motor is rotated in 16.12rad.

ABSTRAK

Projek ini adalah simulasi dan eksperimen penyiasatan ke dalam pembangunan kawalan PID menggunakan perisian MATLAB SIMULINK. Pembangunan simulasi kontroler PID dengan model matematik motor DC dilakukan dengan menggunakan kaedah Ziegler-Nichols dan kaedah cuba and jaya. Parameter PID akan diuji dengan parameter motor sebenar dengan menggunakan pengawal PID pada perisian MATLAB/SIMULINK. Bagi mengaplikasikan pengawal PID dari perisian kepada motor DC sebenar, data 'acquisition card' digunakan. Dari simulasi dan eksperimen, keputusan kecekapan dari pengawal PID dibandingkan dari segi respon dan analisis dilakukan dan dibentangkan. Pada awalnya CVT direka menggunakan perisian Solid Work untuk mengetahui sistem mekanikal dan dimensi penghantaran ini. Kemudian, pengiraan matematik ini dilakukan untuk mengetahui kriteria DC Motor untuk dipilih dan putaran tepat dari motor sebagai sumber utama penghantaran. Motor harus mampu untuk menghasilkan 4.14Nm atau lebih dari torsi dalam rangka mekanisme berfungsi dengan sempurna hingga mencapai limitnya. Motor DC harus memainkan hanya pada 16.12rad atau 2.57 putaran. Oleh sebab itu kawalan PID digunakan untuk mencapai nilai ini dalam simulasi. Selepas menggunakan kaedah cuba dan jaya untuk memutuskan nilai yang tepat untuk nilai malar $K_p = 15$, $K_i = 25$ dan $K_d = 0,15$ dalam sistem kawalan PID untuk memastikan motor DC diputar pada 16.12rad.

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LIST OF SYMBOLS

e	The error between the reference and the output signal system
T_i	The integral time
T_d	The derivative time
K_p	Proportional gain
K_i	Integral gain
K_d	Derivative gain
α	Wrap angles
τ_{in}	Input torques
τ_l	Load torques
J	Moment of inertia of the rotor
b	Damping ratio of the mechanical system
K, K_e, K_t	Electromotive force constant
R	Electric resistance
L	Electric inductance
V	Source Voltage
θ	Position of shaft
h	Increment radius
L_{belt}	Belt length

LIST OF ABBREVIATIONS

CVT	Continuously Variable Transmission
EMDAP-CVT	Electromechanical Dual Acting Pulley Continuously Variable Transmission
PD	Proportional Derivative
PI	Proportional Integral
PID	Proportional Integral Derivative
DC	Direct current

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The internal combustion engine or (ICE) is an engine in which the combustion of a fuel occurs with an oxidizer using air in a combustion chamber. ICE is operates with optimum fuel consumption within a smaller range of its overall operational speed, so transmission gear ratios are designed to keep the engine operating conditions (Tawi, 1997).

Then, continuously variable transmissions (CVT) are designed to overcome this situation for controlling the transmission gear ratio such that the engine is kept operating within this optimum speed range most of the time and at the same time satisfy the driver's demand for more torque during vehicle acceleration. Lately CVT have become great deals of interest in the automotive sector due to the potential of lower emissions and better performance. A CVT is an emerging automotive transmission technology that offers a continuum of gear ratios between high and low extremes with fewer moving parts. This consequently enhances the fuel economy and acceleration performance of a vehicle by allowing better matching of the engine operating conditions to the variable driving scenarios (Sugeng, 2009) .

There are also many types of controller used in the industry, such controller is PID controller. PID controller or proportional-integral-derivative 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 desired set point by calculating and then outputting a corrective action that can

adjust the process accordingly. So by integrating the PID controller to the DC motor were able to correct made by the DC motor and control speed or the position of the motor to the desired point or speed.

1.2 PROBLEM STATEMENT

- i. ICE commonly used for mobile propulsion in automobile, equipment, and other portable machineries. It is almost impossible to run an ICE in optimum control line or maximum power using conventional gearbox.
- ii. Infinite transmission ratio can be control using CVT that allowing the engine to operate at optimum efficiency or fuel efficiency.
- iii. Design a controller is the major challenging to all manufacturers that can match the torque capacity, efficiency, size, weight, and manufacturing cost of step-ratio transmission.

1.3 PROJECT BACKGROUND

Matlab software is used in this project. PID controller is a method of controller to controlling DC motor which is important component to determined gear ratio in this CVT. DC motor provides power to rotate the pinion of EMDAP-CVT, which in turn rotates the gear using a CAM hence creating linear movement of each pulley sheave. A DC motor model is needed to determine the amount of force to move the cam that changes the belt diameter of each pulley. As a result of this project, to design an effective PID controller, three gain parameters, namely proportional, integral and derivative gains need to be specified. The conventional approach to determine the PID parameters is to study the mathematical model of the process and try to use simple tuning parameters that provide a fixed set of gain parameters (Sugeng, 2009).

1.4 PROJECT OBJECTIVE

- i. To design a CVT transmission model using a solid work software.
- ii. To control the position of DC motor with PID controller using MATLAB/SIMULINK application.
- iii. To design the PID controller and tune it using MATLAB/SIMULINK.

1.5 PROJECT SCOPES

The following are the scopes of the study:

- i. Determine the effective rotation (position) of the DC motor that can move the pulley to desired gear ratio.
- ii. Calculate the gear ratio that produced from the CVT design.
- iii. The CVT design or type based on rubber belts.
- iv. Design and produce the simulation of the PID controller.
- v. Simulate the PID simulation with an actual DC motor.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

CVT is a transmission device that is used to provide a set of discrete angular velocity outputs from a constant velocity source. A continuously variable transmission (CVT) serves the same function as a conventional power transmission device. The difference is that a non-discrete range of outputs is produced, and its speed ratio can be varied continuously. The CVT improves vehicle drive ability and passenger comfort as it removes the process of shifting gears in conventional transmission thus avoiding uneven vehicle acceleration.

2.2 BACKGROUND AND BRIEF HISTORY

In the year 1490, Leonardo de Vinci sketched his idea for CVT. CVT already begun in the early era of car development in the same period of conventional automatics. Due to cost concern, General Motors had developed a fully toroidal CVT and conducted extensive testing before eventually deciding to implement a conventional stepped-gear automatic. General Motor Research reworked on CVTs in the 1960s, but none ever saw their production. British manufacturer Austin used a CVT for several years in one of its smaller cars, but it was dropped due to its high cost, poor reliability, and inadequate torque transmission (Yamaguchi.J, 2000). Simple rubber band and cone system is the most material using in the early stage of CVT. It's simply likes the one developed by a Dutch firm, DAF, in 1958. The problem is it could only handle 0.6 l engine, and severe problem with noise and rough starts eventually to hurt its reputation (Birch, 2000).

2.3 ADVANTAGE OF CONTINUOUS VARIABLE TRANSMISSION (CVT)

All drivers are familiar with the clunking sound of shifting transmission. Therefore, CVT is designed to overcome this problem with perfectly smooth and naturally changes its ratio discretely such that the driver or passenger feels only steady acceleration. In theory, as the harshness of shifts and discrete gears force the engine to run at a less than optimal speed, a CVT would cause less engine fatigue and would produce a more reliable transmission (Mori.H and Yamazki, 2001).

CVTs offer improved efficiency and performance. Table 2.1 shows the power efficiency of a typical five speeds automatic, which is the percentage of engine power transmitted through the transmission. This yields an average efficiency of 86%, compared with a typical manual transmission with 97% efficiency (Kluger and Fussner, 1997a).

Table 2.1: Efficiency versus gear ratio for automatic transmission.

Gear	Efficiency Range
1	60-85%
2	60-90%
3	85-95%
4	90-95%
5	85-94%

Source: (Kluger and Fussner, 1997b)

Table 2.2: Efficiency of various CVT design.

CVT Mechanism	Efficiency Range
Rubber belts	90-95%
Steel belts	90-97%
Toroidal traction	70-94%
Nutating traction	75-96%
Variable geometry	85-93%

Source: (Sugeng, 2009)

By comparison, Table 2.2 shows the efficiency range for several CVT designs. Their efficiency depends less on driving habit than manual transmission. Since CVT allows an engine to run at its most efficient point virtually independent of the vehicle speed, a CVT equipped vehicle yields fuel economy benefits when compared with a conventional transmission (Kluger and Fussner, 1997a) .

2.4 CHALLENGES AND LIMITATIONS

The progress of CVT development has been slow due to unsuccessful efforts to develop a CVT that can match the torque capacity, efficiency, size, weight, and manufacturing cost of step-ratio transmission. In addition, the delay in CVT development can be attributed to the lack of demand as the conventional manual and automatic transmission have long offered sufficient performance and fuel economy (Broge, 1999).

One of the major complaints that related to previous CVTs is the slippage in drive belt or roller has been with. The complaints triggered due to the lack of discrete gear teeth, which form a rigid mechanical connection between two gears which friction drives are inherently prone to slip, especially at high torque. A simple solution to this problem which has been used for many years is by limiting the usage of CVTs only in cars with relatively low torque engine. Other than that, another

solution for the problem is by employing a torque converter. However, it will eventually reduce the CVT's efficiency (Yamaguchi.J, 2000).

CVTs can be applied in cars with high torque engine with the improvements in manufacturing technique, technology material processing, metallurgy, advance electronic control and advance engineering. The selection of the ratio is essential as to operate CVT at the optimal transmission ratio at any speed. Manual transmissions have manual controls, where the desired gear ratio totally depends on the driver to shift it while automatic transmissions have relatively simple shifting algorithms. However, more complex algorithm is required for CVT to accommodate an infinite division of speed and transmission ratios.

2.5 VEHICLE MODEL

Transmission of gearbox and the final drive shaft are important component to transmit the engine torque produced by the engine to the wheel. The whole vehicle model including the engine, clutch, CVT and load, and dynamics model of CVT system was developed based on different stages of engaging clutch and studied through simulation, similar study has been carried out by other researchers. They found that a conventional proportional control strategy could not satisfy the control demand for engaging clutch; hence they designed a fuzzy controller for the clutch control and applied self-adjusting PD for the ratio control. The simulation results indicated that the speed ratio controller has good control effect and implements reasonable match between engine and CVT. It demonstrates that the simulation model established is acceptable and reasonable, which can offer theoretical help to devise and develop CVT system (Jun and Long, 2001).

2.6 TRANSMISSION MODEL

A power transmission device whose speed ratio can be varied in a continuous manner is known as CVT. Meanwhile, traditional fixed ratio transmission (FRT) can only vary speed ratio in certain discrete steps.

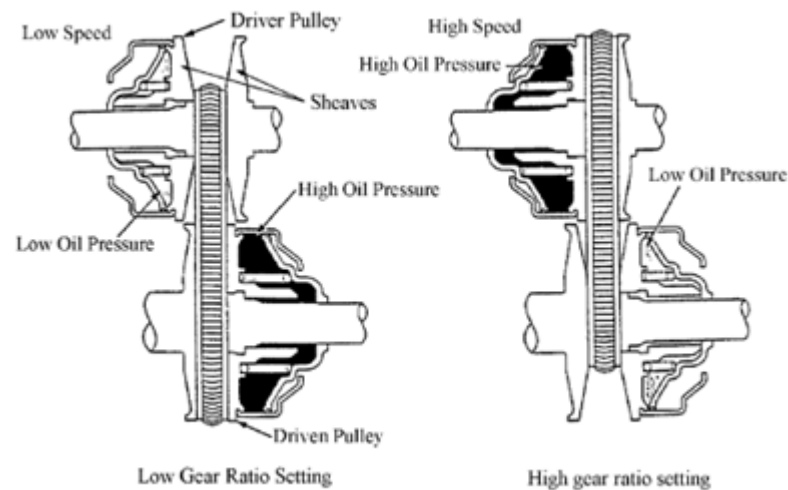


Figure 2.1: Overview of a Van Doome's Belt Driven CVT.

Source: (K.K.Ang et al., 2001)

Figure 2.1 illustrates two types model of transmission system of Van Doome's belt driven CVT.

2.7 CONTROLLER DESIGN

For both linear and non-linear systems, there are using PID controllers because of their simplicity. Adjusting the parameters is needed to controls satisfactory control performance. But the selection parameters for nonlinear systems are always a challenge for the control engineers involved PID. Therefore PID are widely use in simple linear control systems just show in figure 2.2.

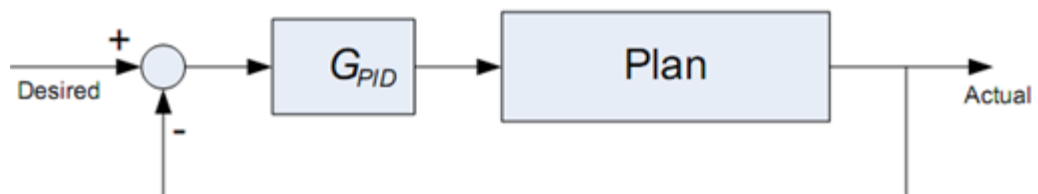


Figure 2.2: A general PID control scheme

The ideal continuous transfer function of a PID (*GPID*) controller is given by

$$G_{pid} = K_p \left(e + \left(\frac{1}{T_i} \right) \int_0^t e \, dt + T_d \left(\frac{de}{dt} \right) \right) \quad (1)$$

Where,

T_d - K_d/K_p

e - The error between the reference and the output signal system

T_i - The integral time

T_d - The derivative time

K_p - Proportional gain

K_i - Integral gain

K_d - Derivative gain

In digital control and for small time sampling (T_s), the equation can be approximated by

$$G_{pid} = K_p(en) + \frac{T_s}{T_i} \sum_{j=1}^n e_j + \frac{T_d(en - en-1)}{ts} \quad (2)$$

2.8 DYNAMIC MODELLING OF BELT CVT

Steel V-belt or a rubber V-belt is commonly used as power-transmitting device in a belt-type CVT. Most of the existing models CVTs are based on the principles of quasi-static equilibrium, which are steady-state model with a few exceptions. In order to achieve the quasi-static equilibrium the analysis is used to develop a set of equations that capture the dynamic interactions between the belt and the pulley. Variable sliding angle approach was implemented to describe friction between the belt and the pulley as the belt is capable of moving both radially and tangentially.