ISSN 2395-1621

Implementation of throttle- by-wire control for a vehicle

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ABSTRACT

In a throttle-by-wire car, a microcontroller determines the correct throttle plate position. Electronic control of this plate offers improved fuel economy and economy by maintaining optimal throttle positions at all times, which otherwise is not humanly possible. The electronic throttle controller uses a physical sensor to read the throttle plate angle. The physical sensor is a circuit which uses a potentiometer to modify the output voltage of the sensor based on throttle plate angle. In this model throttle plate angle is input and a signal representing the voltage is output. The controller in this system is required to convert its output into a standard pulse width modulated signal (PWM). The electronic throttle body opens and closes the throttle plate valve, which controls the amount of air inducted into the system.

***Keywords*: PI - Controller ,Pluse Width Modulated ,throttle System**

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I. INTRODUCTION

The internal combustion, spark ignition engine has been widely used as the dominant form of mechanical work production for consumer automobiles over the century. Throughout this time, advancements in sensing, actuation, and fabrication have greatly improved the production, operation, and reliability of such automobiles.The development of electronic controlled solenoids and motors have greatly facilitated the implementation of electronic valves. This paper discusses and compares the implementation of electronic throttle valve controllers through hard-wired analog circuits and soft-programmed digital microcontrollers. While both valve controller designs may use analog, or variable voltage, and digital, or on/off, signals, the terms “analog” are used to describe the components that make up the controllers themselves. That is, one design uses amplifiers and components for logic, while the other implements logic in code and programming.

The spark ignition (SI) engine uses a spark to ignite gasoline with air to release thermal energy for conversion to mechanical work. For the oxidation of gasoline to occur properly, a specific ratio between fuel and air must be preserved for optimal combustion. This ratio, called the air

fuel ratio, asserts that for every unit by mass of gasoline, 14.7 units by mass of air must also be present in the combustion chamber during ignition.[Heywood J.B.] If there is too much air, the mixture is said to be lean. If there is not enough air in the mixture, it is said to be rich. The two components that directly control the amount of air and fuel per cycle in an SI engine are the fuel injectors and the throttle valve. They represent two of the most important components in the spark ignition (SI) engine.Fuel metering and intake air control were once performed together a component called the nineteenth century and used as the predominant mechanism for air and fuel neatening until the late 1980’s. The carburetor was comprised of two main components: the butt early valve and the fuel metering venture and jet region.Thecarburetor’s operation relies on fluid mechanics to mix fuel with air. As air enters the carburetor, it will be forced into the narrow section, venture, which will accelerate the air travel.

Bernoulli’s principle indicates that the faster air travels, the lower its static pressure, will be. As the accelerated air in the venturi passes the fuel jet, the lower pressure will pull fuel out of the jet for mixture. The amount of air there passes through the carburetor is controlled by the butterfly valve below. The more the valve is turned, the more air is pulled into the intake manifold by the pumping action of the pistons [Heywood J.B.].

The development of solenoid actuation and electronic control made precise, reliable electronic fuel injection systems reality. This lead to the separation of air and fuel control through an intake air throttle valve and electronically controlled fuel injectors. The throttle valve assembly, or air into the engine intake manifold. It accomplishes this using both an electric motor driven butterfly valve, as well as an angle sensing throttle position sensor (IPS).

The signal from the throttle position indicates the angles of the butterfly valve and can be used to ensure proper actuation of the throttle valve based on desire angles. The throttle body's electric motor and throttle position sensor must be coupled with a capable electronic controller for operation.

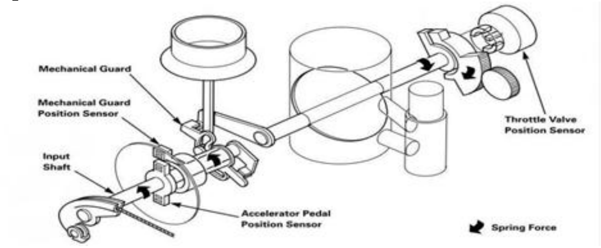


Figure 1 Simplified view of Throttle-by-wire

The throttle body's electric motor and throttle position sensor must be coupled with a capable electronic controller for operation. The throttle controller consists of signal processing logic and components that use the throttle position sensor signal of valve angle as feedback when attempting to drive the valve to a desired angle. This controller can be composed of purely electronic components such as SIGNIFICANCE AND PROBLEM DEFINITION

The automobile is an integral part of modern society. With each passing year come new advancements to this marvel of mankind's ingenuity. The main area of development is one commonly referred to as Drive-by-Wire. This is a generic term used when bulky and inaccurate mechanical systems are replaced with sophisticated electrical components. Implementation of Drive-by-Wire usually results in more efficient processes and increased performance. Some of the major areas being considered for X-by-Wire development are steering, braking, suspension, and engine management.

Conventional automotive throttle systems transfer the driver input on the foot pedal via a cable to the throttle body. A rotary movement in the throttle body butterfly valve controls the air flow into the engine, and thus the engine response. Electronic throttle control replaces the mechanical link with electronic sensors, and an electrically actuated butterfly valve is controlled. The alternative to the drive-by-wire electronic throttle system is the standard pull-cable throttle with return spring. This is still the predominant solution in use in passenger cars. There are a number of ways in which the electronic throttle system performs better than the mechanical linkage. The only disadvantage of the drive-by-wire solution may be the cost. A natural concern about removing the mechanical linkage between the accelerator pedal and the throttle mechanism is that the non-mechanical system might be inherently less safe and less reliable. The drive-by-wire system can, in fact, be more reliable particularly when considering problems with sticky and dirty throttle bodies. The electronic system can adapt to the friction in the system in order to maintain the accelerator pedal tracking performance. Hardware and software redundancy can be used to maintain a very high level of reliability. Integration of various engine and vehicle control systems can be accomplished with a single TBW system and can offset the additional cost of the hardware. Cruise control, idle control, engine over-revolution protection and traction control features might all need to modify the throttle position. With this system, the switching or blending of control algorithms occurs in software and there is no need for separate actuation components for each feature. There are also advanced features that can be accomplished only with the TBW system. If multiple throttles are used, sophisticated engine power management can shut down individual cylinders and, in doing so; increase the efficiency of the power cycles in the other engine cylinders. The replacement of the connection between the driver's foot and the throttle plate with software allows the designer to adjust the pedal-to-plate transfer function. For instance, initial pedal travel can correspond to smaller throttle plate motion compared with pedal travel closer to the wide-open-throttle (WOT) position. This transfer function can also be adjusted for vehicle speed or altitude to make the engine feel more responsive to the driver.

Literature Review:The development of the electronic Throttle-by-wire (DBW) throttle system is an important research tool that provides a way of regulating the changes in air flow into the manifold caused by the throttle movement. The shock-jerk phenomenon is usually observed in vehicles with manual transmission systems that are rapidly accelerating, and this phenomenon makes the assenger feel uncomfortable. This phenomenon can be minimized using torque control of the vehicle with throttle-by-wire or an ETC (Electronic Throttle Control) system. Park et. al., in their work modelled, the drivetrain of the vehicle to simulate the vehicle behavior. The control strategy of Throttle-by-wire was studied to reduce shock and jerk characteristics. The control logic was verified by using vehicle modeling and simulations.

An electronic throttle consists of a DC motor, spur gears, a return spring, a position sensor, power electronics and an electronic control unit. Fast and precise position control of this electromechanical system is relatively difficult due to very high friction and the strong nonlinearity of the spring. Grepl et.al., have described two new controller structures suitable for different reference signal types.

The electronic throttle promotes the development of electronically controlled vehicle systems. As the technology advances and the cost reductions, the electronic throttle has been widely used in modern cars. With the continuous progress of the domestic automobile manufacturers and domestic universities, electronic throttle has been applied in various models. In hybrid vehicles, the continuously variable transmission vehicles, the natural gas engines, diesel engines, and motorcycles the electronic throttle is applied in research and obtain the corresponding scientific research. In the future of the car electric system, the electronic throttle will play an increasingly critical role and obtain the wide range of applications. Sun et. al., have given details of Development and Application of Vehicle Electronic Throttle.Electrically actuated control devices for regulating the amount of air entering gasoline engines play an essential role in drive-by-wire applications. Reichhartinger et.al., in their work have outlined an approach to the control electronic throttle valves.

Electrically actuated control devices for regulating the amount of air entering gasoline engines play an essential role in drive-by-wire applications. In this paper an approach to the control of so-called electronic throttle valves is outlined. First a standard sliding-mode controller is presented. It is shown that the performance of the feedback loop can be improved significantly by incorporating time-variable boundary layers

Angerd and Johansson in their work have carried out Design and implementation of a central control unit in an automotive drive-by-wire system.

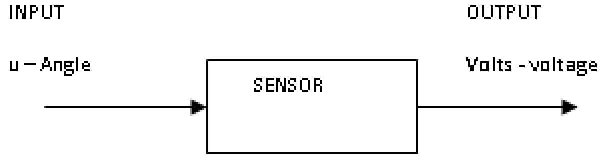
SCOPE OF WORK :

1. Modelling of Potentiometer (sensor model). It is a variable resistor. As the throttle plate opens and closes, the resistance of the potentiometer changes. In this way it acts as sensor that converts the throttle body angle in radians to voltage.

2. The controller must convert its output to a standard pulse-width modulated signal (PWM). The task in this section is to start with the signal output of the controller and translate it into a duty cycle and direction so that it may be passed as an input to the throttle system. The conversion from the controller output to duty and direction is modelled with a set of logical equation.PI controller (Proportional and Integral) for the throttle system is modelled in this section. In a throttle-by-wire car, a microcontroller determines the correct throttle plate position. If the driver needs sudden acceleration and steps on pedal, a sensor transmits driver's pressure on the pedal to the microcontroller.In this part dynamics of throttle is modelled. It contains a butterfly valve that opens when a driver presses down on the accelerator pedal. The opening angle is controlled by a DC motor and the spring attached to it returns it to closed position. The amount of rotation is limited to 90 degrees. There are two inputs for the throttle model, duty cycle and direction of torque.Input is in terms of pressing of pedal and output in terms of throttle plate angle. Objective is to achieve throttle plate angle close to desired pedal input.

SENSOR MODEL

The electronic throttle controller uses a physical sensor to read the throttle plate angle. The physical sensor is a circuit which uses a potentiometer to modify the output voltage of the sensor based on throttle plate angle. The model of the sensor accepts the throttle plate angle as an input and outputs a signal representing the voltage of the sensor output.



MODELLING THE SYSTEM WITH EQUATIONS :

The following equation describes the relationship between the angle in radians, u, and the output voltage, y. The standard BMW X5 throttle system is a by-wire system where two sensors are used to determine the throttle pedal position. The first sensor outputs a voltage from 0.5 to 4.5 V.

Angle indeg = 180/(π x u)

y = 0.5 V if angle = 0^0 and

y = 4.5 V if angle = 90^0

The equation states that y should be 0.5V when the angle is 0^0 and 4.5V when the angle is 90^0. A lookup table to interpolate the value of y for input angles between 0^0 and 90^0 is created.

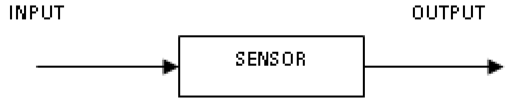


Figure 2. Schematic of the sensor

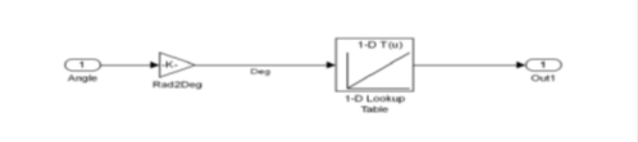


Figure 3. Simulink model of the sensor

PWM Conversion

The controller must convert its output into a standard pulse-width modulated (PWM) signal. In this portion the aim is to start with the signal output of the controller and translate it to a duty cycle and direction so that it may be passed as an input to the throttle system. The conversion from the controller output to duty and direction is modelled with a set of logical equations.The variables in these equations are the controller output (u), duty cycle (duty), and the direction of the torque to be applied to the throttle plate (direction). The controller output, u, is the system input, and duty and direction need to be defined as system outputs. Both duty and direction are directly computed from the input signal.Duty cycle is the fraction of time over the period of the carrier signal during which a component, device, or system is operated.

The system input is the Controller output and duty and direction are the system outputs.

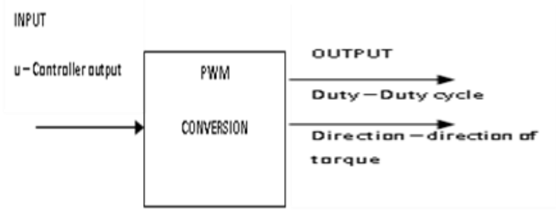


Figure 4. Schematic of the PWM conversion block

Duty = 0 u0 if 0<= 0 u 0 <=1 and

Duty = 1 if 0 u 0 >1

Direction = 1 if u>=0 and

Direction = 1 if u<0

Duty – Duty cycle of PWM signal. Duty cycle must fall within the range of 0<= duty <=1, where 0 maps to the device operating with a 100% duty cycle.

Direction – Direction in which torque should be applied to the throttle plate

PI (proportional-integral) Controller :

In a throttle-by-wire, a microcontroller determines the correct throttle plate position. If the driver needs sudden acceleration and steps on the acceleration pedal, a sensor on the pedal transmits the driver's pressure on the pedal to a microcontroller. The microcontroller calculates and relays the correct throttle position to the motor, which moves the throttle

plate.Electronic control of throttle plate offers improved fuel economy and emissions by maintaining optimal throttle conditions at all times. Additionally, it allows for more advanced features such as traction control, where the throttle position might be modified to prevent the wheels from slipping on the road.In the electronic throttle control model, the proportional-integral (PI) controller is the throttle plate position controller. The PI controller modifies the control output based on error between the desired throttle plate position and actual throttle plate position.

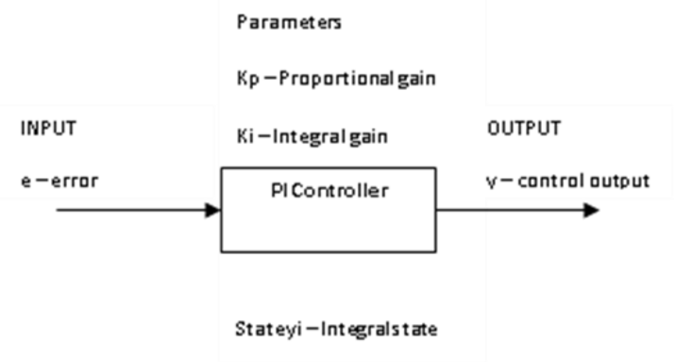


Figure 5. Schematic of the PI controller

Mathematical modelling of the PI controller with equations :A discrete PI controller is used as the electronic throttle controller based on following equation: y(k) = yp(k) + yi(k) where

yp(k) = Kpe(k)

yi(k) = yi(k-1) + KiTs e(k)

-1<= yi(k)<=1

y(k) – Controller output

e(k) – Error (Difference between desired output and actual output)

Ts – Sample time

Kp – Proportional gain

Ki – Integral gain

The backward Euler method (a numerical integration approximation) is used to solve the integrator equation from above.

The output of the integrator equation must fall between -1 and 1. This range is required to prevent windup in the system. Windup refers to a condition when the controller is ineffective at reducing the system error, and so the integral state (yi(k)) becomes very large.

Throttle System:The throttle in an engine controls the flow of the throttle motor. The throttle in an engine controls the flow of air/fuel mixture to the cylinders. The throttle body contains a butterfly valve that opens when the driver presses down on the accelerator pedal. This lets more a/f mixture enter the cylinders making the engine run faster.The opening angle of the butterfly valve is controlled by a DC motor. Thereis also a spring attached to the valve to return it to the closed position when the DC motor is deenergised. The amount of rotation of the valve is limited to approximately 90 degrees, through the use of hard stops.The throttle takes a converted torque as an input and computes the throttle plate position as an output. The dynamics are a function of position, angular velocity, viscous friction, inertia, kinetic friction and torque.

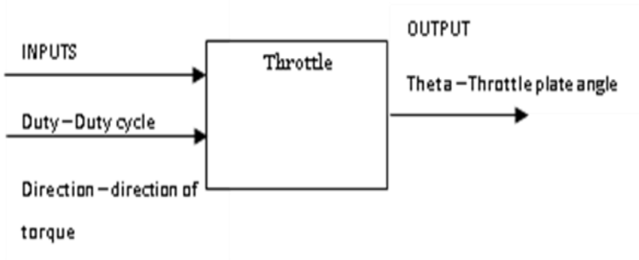


Figure 6. Schematic of the PWM conversion block

Parameters

J – Inertia of throttle plate (kg-m^2)

K_s – Spring constant (Nm/rad)

K_d – Viscous friction constant (Nms/rad)

θ_{eq}– Spring equilibrium constant

C_s – Torque constant

$\theta(t)$ – Throttle angle

$\dot{\theta}$ (t) – Throttle angular velocity

Modelling the throttle system with equations :

The throttle plate dynamics can be modelled mathematically by summing the torques about the throttle plate shaft. There are three torques acting on the shaft being considered:

i. The torque from return spring
ii. The viscous friction torque
iii. The torque applied by electric motor

The complete system is modelled with the following equation:

$J\ (t) = \Sigma\ T\ (t) = T_{motor}\ (t) + T_{spring}\ (t) + T_{damping}\ (t)$

$T_{motor}\ (t) = (Direction)(Duty)C_s$

$T_{spring}\ (t) = -K_s\ (\theta(t) - \theta_{eq})$

$T_{damping}\ (t) = -K_d\ (\ \ (t))$

$J\ (t) = (Direction)(Duty)C_s - K_s\ (\theta(t) - \theta_{eq}) - K_d\ (\ \ (t))$ for $0<=\theta<=\pi/2$

The presence of hard stops limits the angle between 0 and $\pi/2$ for the actual throttle plate.

Angular acceleration is given as:

$(t) = 1/J((Direction)(Duty)C_s - K_s\ (\theta(t) - \theta_{eq}) - K_d\ (\ \ (t))$ for $0<=\theta<=\pi/2)$

Electronic Throttle Control:

Complete Electronic Throttle control implementation will be achieved by combining all above mentioned models as shown in figure.

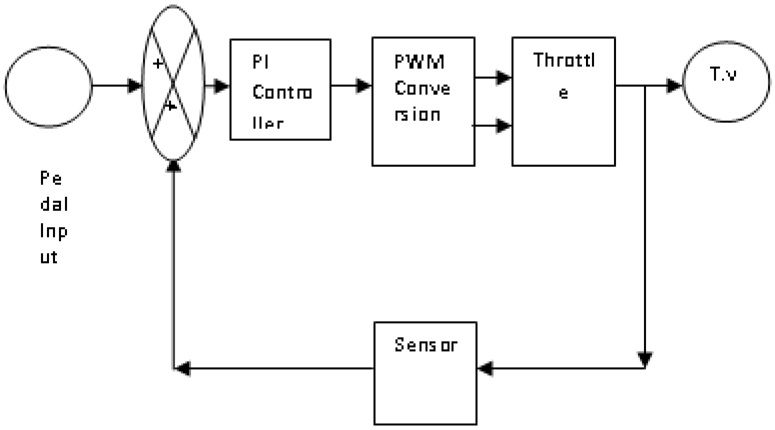


Figure 7 Schematic of the Electronic Throttle Control

CONCLUSIONS

From above it conclude that the efficiency of the engine increases, & it also controls the fuel by throttle valve,& also controls the hazardous gases inside the engine.

ACKNOWLEDGMENT

Thanks to Prof. AnuragNema for his valuable contribution in developing the IJRSD article template.

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