Automotive Engine Idle Electronic System Design and Test

Feng Xueli

Hangzhou Polytechnic, Hangzhou
Zhejiang311402, China

***Abstract* — The idling of engine has natural and random fluctuations of rotation speed caused by variations in engine intake, volatility of exhaust and randomness of combustion, which are all present during the idling state. Changing ignition advance angle can rapidly control the rotation speed accurately, the reason for which is that ignition advance can influence the torque of engines. The research reported here aims to design fuzzy algorithms to control the idling speed of automotive engines. The output of fuzzy interference is duty cycle ratio and ignition advance ratio of air bypass valve control signal. The engine bench test results indicate that the method can shorten warm-up time and stabilize speed fluctuation during idling, and the control effect of idling stability is equivalent to the original engine.**

Keywords - Automotive Engine, Idling Control, Fuzzy Control Technique

I. INTRODUCTION

From the perspective of the development of gasoline injection technique, the original intention to develop it is to solve the problems that aerial engine can't fly curve by using carburetor,and carburetor freezes and fires [1]. Initially, we applied the experience of diesel engine, injection technique. In 1898/1901, Deutz Corporation applied gasoline injection technique for internal combustion engine. In 1912, internal combustion engine Corporation began to develop gasoline injection device. In 1930, Schnauffer, the doctor of DVL in Germany, began to apply diesel injection pump to penetrate gasoline into high-pressure cylinder, and the cooperated with Bosch Corporation to research gasoline injection in 1933. In 1935, after researching the parts for many years, Benz Corporation developed DB601E engine of gasoline injection, and developed DB601L gasoline injection engine for Lufthansa German Airlines in 1939. It not only improves the power, but also reduces oil consumption rate.

Idle control ways include open-loop control and closed-loop control. Under the condition of stable idle, closed-loop control is mostly uses, and the applied feedback signal is engine speed signal.

Fuzzy control method is appropriate for the conditions that mathematical model is difficult to be established or can't be established. The method can process the qualitative information of objects and the experience and skills of applying man. So it is appropriate for controlling time varying, nonlinear and multi-factor complicated process of idle of automotive engines. Fuzzy technique has been widely applied in some electro-control subsystem, and has achieved evident control effect.

The idle of engines has natural and random speed floating because of the randomness of burning, only making feedback on idling air input can't overcome speed fluctuation. But ignition advance can control the rotation speed of engines, and influences the idling speed. So idle stability can be improved by controlling ignition advance angle. It has a hysteresis process from the change of any control parameters to the change of engine performance parameters, but the hysteresis progress is different. When idle speed control bypass air is changed to change the idling speed, the hysteresis is about 360oCA. But when ignition advance angle is changed to control idling speed of stable idle, the hysteresis is only 90oCA. Therefore, it is rapid and accurate to change ignition advance to control the idle speed under stable idling conditions.

II. COMPOSITION AND OPERATION PRINCIPLE OF MULTI-POINT GASOLINE INJECTION SYSTEM

The function of electronically controlled gasoline injection system is to provide certain gasoline for engines according to the real-time air input of engines, for realizing the combustion with the expected air-fuel ratio.

Oil supply system is shown in Figure 1. It consists of electric gasoline pump, fuel filter, fuel rail, fuel pressure regulator and fuel injector.

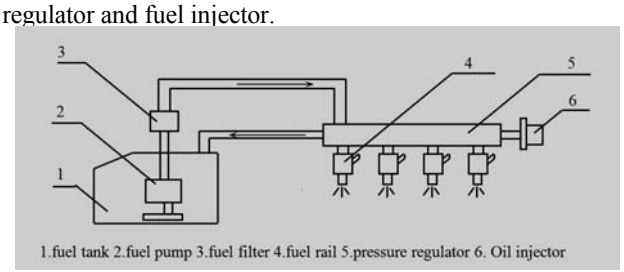

Figure 1. Oil supply system

A. Fuel pump

The function of fuel pump is to provide the required fuel for fuel injectors. Fuel pump is divided into wet and dry. The wet pump is called outside pump, and is installed in oil transferring pipeline out of fuel tank. The advantage is the freedom degree of installation is great. Compared with wet pump, the dry pump is easy to have air resistance and fuel leakage, and the noise is great, so it is not generally used. Wet pump is called inside pump, and it is installed in fuel

tank. It has the advantages of little noise and stable operation performance. The control system uses wet fuel pump.

B. Fuel pressure regulator

Fuel pressure regulator plays the role of adjusting fuel pressure to make that the oil pressure in oil pipelines maintain a certain, which makes the fuel injection quantity of injectors only relate to injection time. The structure of fuel pressure regulator is shown in Figure 2. A diaphragm with clamping flanging divides the lumen into two chambers, spring chamber and fuel chamber. Spring chamber connects with inlet manifold by a pipeline. When the vacuum degree of inlet manifold is low, the diaphragm seals the oil returning port under the function of spring force, and the oil pressure in pipelines increases. When the intake vacuum is great, the diaphragm is absorbed towards spring chamber, and the valve opens pressure relief, which ensures that the differential pressure on both sides of injectors keep invariant.

C. Oil injector

The operation principle of oil injector is a magnetic valve, and the structure is shown in Figure 3. The oil injector has a magnetic coil. The valve needle on the top of the oil injector connects with armature knot. When magnetic coil energizes, it generates magnetic force, and the fuel is injected from the gaps of valve needle with the form of mist spray.

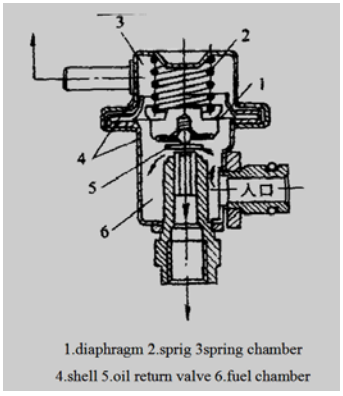

Figure 2. Fuel pressure regulator

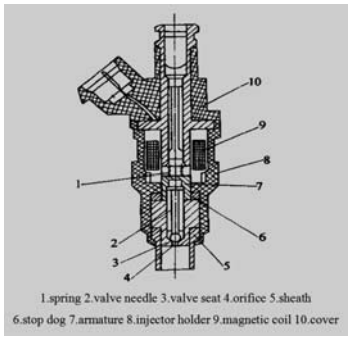

Figure 3. Fuel pressure regulator

III. HARDWARE CIRCUIT OF CONTROL SYSTEM

A. Single-chip system

The control system uses 80C196KC single chip as the central controller. The single chip is a 16-bit machine, and has the following characteristics.

(1) The arithmetic logic unit of CPU is not conventional accumulator structure (MCS-51 series), and it is register-register structure. The operation of CPU directly faces 488-byte register, and has no the bottleneck effect of conventional accumulator structure, which improves operation speed and data throughput capability.

(2) It integrates 10-bit and 8-channel A/D converter and has sampling holder, which makes it easy to be used for composing data acquisition system.

(3) It has four high-speed input channels and 6 high-speed output channels (HSI.2 and HSO.4, and HSI.3 and HSO.5 use the same pin), and it is easy to be used.

(4) It has an efficient instruction system. It can operate the system with symbolic number and without symbolic number. It has the instructions of 16 bit multiplying 16 bit. And the operand instruction improves the instruction efficiency greatly.

(5) The state period is acquired after frequency dividing of oscillator signal (the state period of 8096 is three times of periodic oscillation). It is the basic time unit of chip operation, so the operation speed is high.

B. Circuit design of signal acquisition system

Signal acquisition system is an important part of electronic control system, and it is the interface of sensor and controller. It has direct relationship with the quality and reliability of signals, and the control quality of the system. It is an important channel that each interference enters the system. So it is an important part of system anti-interference design.

Cylinder detection signal and TDC positional signal processing circuit

The system uses HK-1 Hall sensor to collect cylinder detection signal and TDC positional signal. The sensor has the advantages of stable operation, long lifetime, easy to process circuit and good anti-interference performance. HK-1 Hall sensor is open-collector output. When S pole of magnetic steel is close to the sensor, the signal output side conducts, and the signal indicator lights up, which means that there is signal output. When the S pole of magnetic steel leaves the sensor, the signal output side opens circuit, and the sensor indicator is dark, which means that there is no signal output. In the processing circuit, the output signal connects with the high-speed input pin of single chip after reverse, and the function of reverser is to stabilize the level of sensor signal. The designed signal processing circuit is shown in Figure 4.

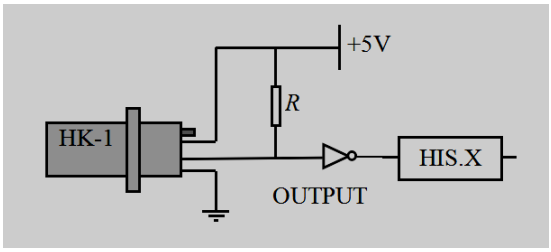

Figure 4. Cylinder detection signal and top center position signal processing circuit

Water temperature measurement circuit

Water temperature sensor is the thermistor with negative temperature coefficient. With the increase of water temperature, the resistance value reduces. In the interface circuit with single chip, the way of voltage division circuit is used to transform the change of resistance value into the change of voltage. And A/D converter is used to implement the conversion from analog quantity to digital quantity. In the conversion, in order to keep the stability of voltage division circuit, the system uses integrated operational amplifier to stabilize the voltage of bleeder circuit, as shown in Figure 5.

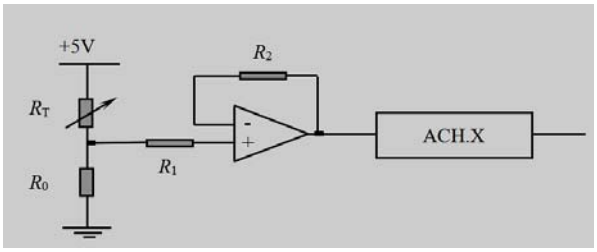

Figure 5. Water temperature measurement circuit

Start signal processing circuit is shown in Figure 6.

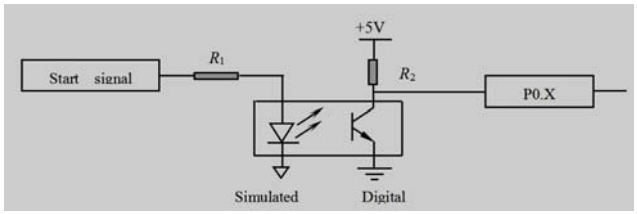

Figure 6. Start signal processing circuit

(4) Oxygen sensor signal processing

The oxygen sensor of the control system is cobalt oxide type. When the gas mixture is strong, the oxygen sensor outputs high level signal. When the gas mixture is sparse, the oxygen sensor outputs low level signal. For theoretical air-to-fuel ratio, the oxygen outputs signal, as shown in Figure 7. According to the feature of the oxygen sensor, it can implement feedback control of air-fuel ratio.

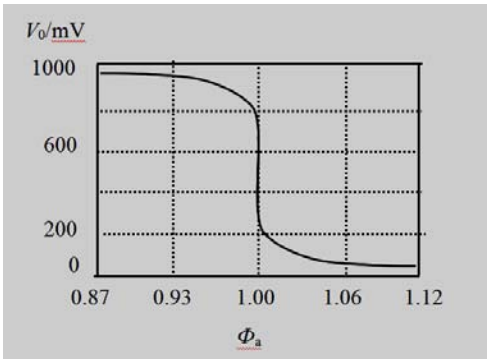

Figure 7. Relationship of air fuel ratio and oxygen sensor output voltage

The designed oxygen sensor signal processing circuit is shown in Figure 8.

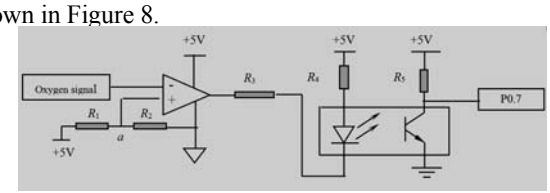

Figure 8.Oxygen sensor signal processing circuit

The output voltage of oxygen sensor is inputted into operational amplifier. Compared with 0.5V in a point, when the sensor voltage is higher than the voltage in a point, the voltage comparator outputs low level, and the photoelectric coupler conducts. P0.7e pin input of single chip is high level, which indicates the mixture is too rare.

Battery voltage processing circuit

Battery voltage is different under different operation conditions of engines, and is greater than the designing range of A/D converter. Therefore, it needs to be normalized for A/D conversion. The circuit is magnified by the differential motion consisting of operational amplifier. The rangeability of supply voltage is from 5~15V to 0~5V. In Figure 9, the output voltage V is

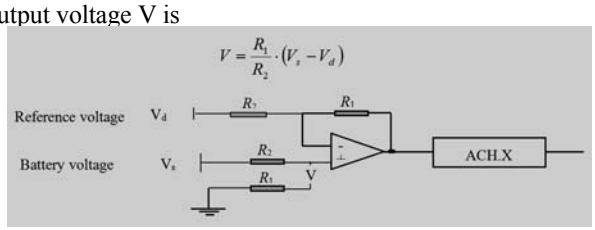

Figure 9. Battery voltage processing circuit

C. Design of power driving circuit Circuit

The signal inputted by 80C196KC single chip is TTL level, and can't operate actuator. So driving circuit required.

(1) Injector driving circuit

The control system uses fuel injection, so there are four same driving circuits, which is controlled by high-speed output HIS.1、HSI.2、HSI.3 and HSI.4.

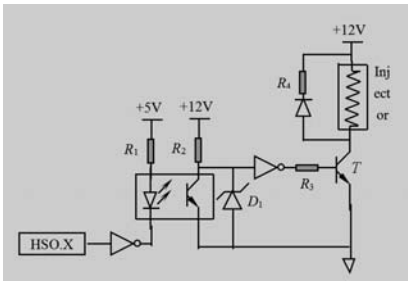

Figure 10. Oil Injector driving circuit

The oil injector used electronic fuel injection gasoline is low resistant （0.6~3 Ω）and high resistance（12~17Ω）. The actuator of oil injector includes current driven and voltage driven injector. The current driven is appropriate for low-resistant oil injector. Voltage driven is appropriate for high-resistance oil injector and low-resistance oil injector. The resistance value of the oil injector used in the control system is 16.3Ω, so the driver design is voltage driving, as shown in Figure 10.

Ignition driving circuit

The ignition driving circuit is shown in Figure 11. Photocoupling coupler component plays the role of transmitting control signals and cutting off interference ways.

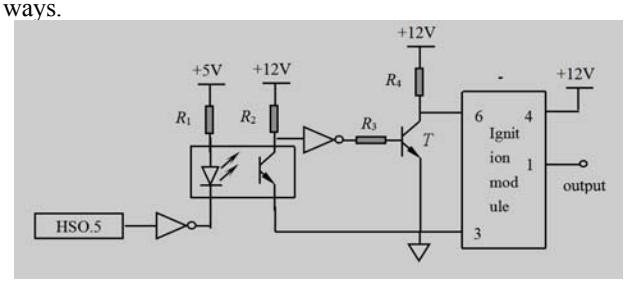

Figure 11. Ignition driving circuit

When HSO.5 pin outputs high level, the photocoupler conducts, and the power triode in conducting state. The ignition module 6 in low level, which makes pin 1 in low level. The primary coil current circuit closes, and is the charging state. When HSO.5 pin outputs low level, the photocoupler ends, so does the power triode. The ignition module pin 6 is high level, which makes the pin high level. The initial coil current circuit cuts off, and the secondary coil senses the high voltage.

(3) By-pass air regulation valve driving circuit

The experiment selects proportional magnetic valve as the by-pass air regulation valve, and uses PWM signal for control. Under the condition without current, the valve is open. According to the difference of current flow,the valve is closed under reversed current. In order to realize the change of valve opening from 0 to 100%. The driving circuit uses twin-type relay to control the current flow of oil injector coil. The driving circuit is shown in Figure 12.

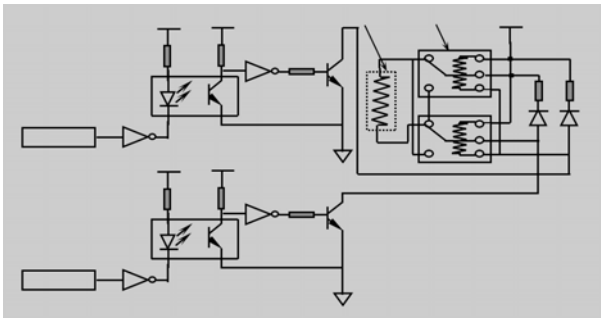

Figure 12. By-pass air valve driving circuit

IV. CONTROL SOFTWARE DESIGN

A. Master control program

The engine operates periodically, which determines that the master control program receives looping execution. When the master control system operates, each subprogram is called to realize the expected control function. The master control program is the central part of the control software. It includes system initialization, starting, judgment of engine conditions and various processing programs. The master control program is shown in Figure 13.

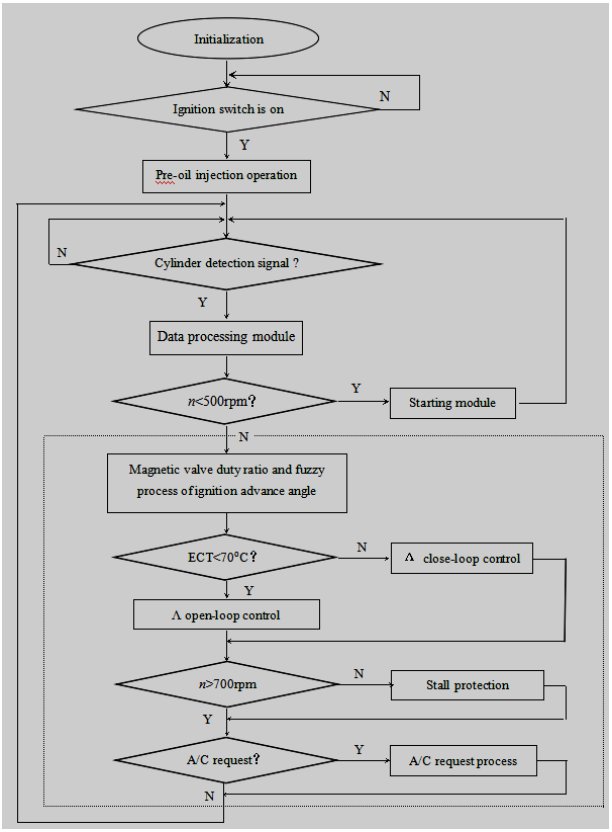

Figure 13. Master control program circuit

B. Master control program

The framework of fuzzy processing program is shown in Figure 14.

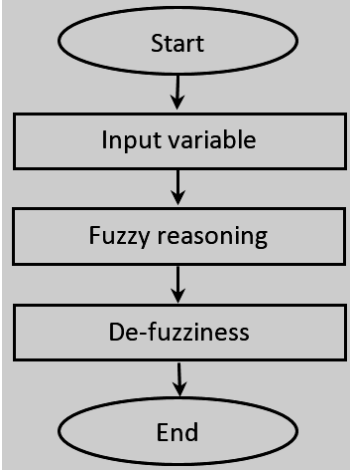

Figure 14. Fuzzy processing program

1. Fuzzization of input variables

The paper uses the input variable Δn (speed deviation) as an example to indicate the fuzzization process. P1(i), P2(i) , P3(i) and P4(i) are four peaks of the tapezoid. U is the membership function value, and the length is a byte in the program, add is the first address, and i is the serial number of fuzzy subset (i=0~6） . The program avoids the operation of symbolic number, so Δn fristly receives symbol judgment.

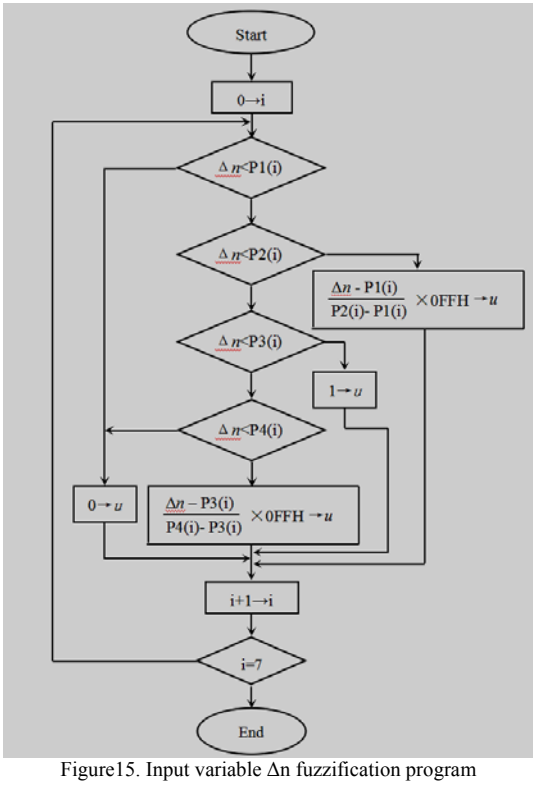

Figure15. Input variable Δn fuzzification program

2. Rule reasoning program

Min-Max rule reasoning method is used, and the framework of fuzzy reasoning program is shown in Figure 15. Add1 is the first address of Δn variable area, Add2 is the first address of ń variable area, Add3 is the first address of output variable area, and RAD is the first address in rue area. I and j is fuzz subset sequence (i、j=0~6）,Temp1、Temp2 、Temp3、Temp4 is the temporary register, and P is rule address counter.

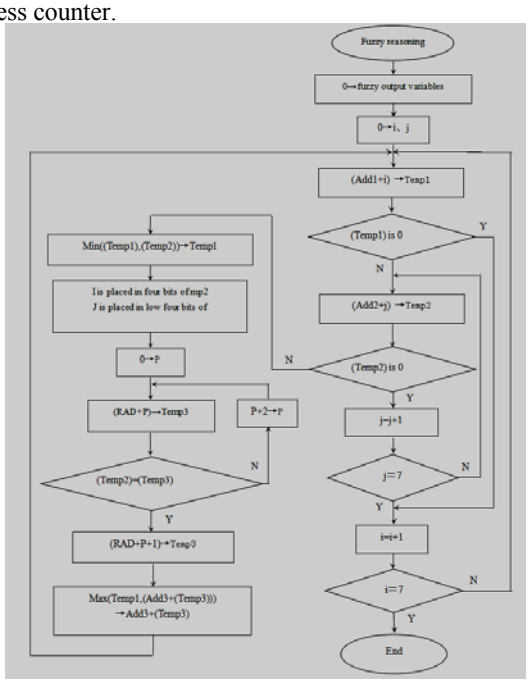

Figure 16. Fuzzy reasoning program

V. CONCLUSION

The main content and achieved conclusions are as follows.

(1) 80C196KC single chip is selected as the controller, and the paper designs engine idling control system with gasoline injection, ignition control and idle speed function. The paper selects the stability of engine idle speed as development targets. And fuzzy control method is used to research idle stability of automotive engines, and it has achieved evident effect.

(2) In fuzzy control algorithm design, inputting membership functions uses the row-echelon form, Compared with traditional look-up table method, it has the characteristics that the output is smooth, and the information is not easy to be lost. Fuzzy reasoning program separates from reasoning rules. Fuzzy reasoning rule uses the data structure of fuzzy subset number, which not only saves storage memory, but also reduces reasoning execution time of controller and is easy to be modified.

(3) The paper designs the measurement device with the feature of oil injector. The device has the advantages of easy test and accurate measurement.

(4) The paper makes anti-interference on the control system, which ensures the stability of the system and reliable operation.

(5) The original control system of engine is compared with idling fuzzy control system in the paper, the experiment results indicate that fuzzy control system has effective and stable idle speed.

The experimental conditions are limited, so the control system needs to be improved, as follows:

- Accurately matching ignition time and fuel-injection quantity under idling condition.
- Increasing fault self-diagnosis function.
- Process for load accessing (such as air condition compressor, power steering and cooling fans).

REFERENCES

[1] Ni Jimin, Zhou Huafu, Development of gasoline injection technique, Micro/mini Internal Combustion Engine, 1996,2,pp.123-135.

[2] Ma Fanhua, Development and research of electronically controlled injection engine, Vehicle Engine, 1994,12,pp.412-423.

[3] Ni Jimin, Principles of automotive combustion engine, Tongji University Press, 1997.7, pp.294-330.

[4] Robert N. K. Loh, et al. Optimal Idle Speed Control of an Automotive Engine. SAE 1998,78,pp.90-98.

[5] Tohru Takahashi, Takashi Ueno, et al. A Simple Engine Model for Idle Speed Control. SAE850291, 1985,123,pp.678-689.

[6] Hiroshi Yamaguchi, Satoshi Takizawa, et al. Analysis on Idle Speed Stability in Port Fuel Injection Engines. SAE paper, 1986,12,pp.90-98.

[7] H. Ando and M. Motomochi. Contribution of Fuel Transport Lag and Statistical Perturbation in Combustion to Oscillation of SI Engine Speed at Idle. SAE paper,2012,78,pp.345-356.

[8] Yashihiro Nishimura and Katsuruki Ishil. Engine Idle Speed Analysis and Control. SAE paper ,2002,87,pp.12-30.

[9] S. Washino, R. Nishiyama, et al. A Fundamental Study for the Control of Periodic Oscillation of SI Engine Revolutions. SAE paper 2013,23,pp.45-60.