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Design and research of Ignition system for small gasoline engine electronic control

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Abstract. In order to promote development and propose effective method for small electronically controlled engine system, a electronically controlled ignition system was designed in this paper. Freescale MC9S12XEP100 is chosen as MCU, control strategy was defined with MC33812 to pre-drive ignition. At last, 168F engine is adopted as original machine, optimum ignition advance angle was calibrated, related correction paraments and formulas were defined. Bench experiments results shows that power performance, fuel consumption and emission performance are promoted and improved significantly after the designed ignition system was adopted.

Introduction

Small gasoline engine, due to simple structure, good mobility, low prices and other characteristics, widely used in garden equipment, agricultural machinery, non-road vehicles and other equipments, has become second only to the second largest car gasoline models, with small gasoline engine output rising, harmful emissions pollution to the environment can not be ignored. In order to control pollution to the environment effectively, the United States, European Union, Japan, as the representatives of the States, has developed and implemented non-road gasoline engine emissions regulations, our state in March 2011 formally implemented the "GB26133-2010" national standards, formulates and restricts emissions from non-road mobile machinery small spark ignition engine exhaust pollutants.

Due to volume, using objects and restrictions of small gasoline engine, coupled with harsh operating conditions, it is not easy to use such techniques in the car like multi-valve, turbocharge, exhaust gas recirculation technology, which led to traditional small gasoline engine develop relative slowly, mechanical control system is increasingly difficult to meet energy conservation requirements [4][5]. While using electronic control technology can make engine performance match optimum value in various conditions, thus achieving energy saving target. As an important part of gasoline engine electronic control system, ignition system directly affects the engine power, fuel consumption and emission performance [1][2].

The system will be designed based on small gasoline engine characteristics, feasibility and superiority will be verified through experiment, new solutions and useful reference for development will be proposed.

Small Gasoline Engine Ignition System Design Scheme

Main parameters of ignition control system are ignition advance angle and ignition continuous angle. The two parameters are determined by engine speed, load, body temperature, air pressure, and battery voltage.Restricted to size and cost limitation, the system can not use too much components, which will increase developing cost and wiring difficulty. Because of most small gasoline engine are 4-stroke single cylinder engine, this system will use inlet pressure to judge the phase, when obtained pressure signal is in decreasing sequence, the intake stroke will be determined by system.

Considering above factors, the designed system structural arrangement is shown in Fig.1, the system will use fewer sensors and actuators to achieve control and optimization for these relevant parameters. Basic ignition advance angle is based primarily on engine load and speed, other sensor signals are used for correction. Ignition delay angle is corrected by real-time monitor of battery, according to voltage correction, the spark plug can get sufficient energy.

Small Gasoline Engine Ignition System Design

Ignition system is combined with hardware and software, the two parts will be described in detail.

Hardware Design. Hardware consists of sensors, ECU and actuators.

Sensor. Crankshaft position, inlet pressure, throttle position, body temperature sensors are used to get engine information in real time.

+12V powered Hall effect crankshaft position sensor is adopted, trigger signals generated is to judge crankshaft position and calculate speed based on frequency. TPS is a precision sliding potentiometer, used to obtain current throttle open valve and reflect real-time load condition, ECU can get MAP data to obtain current basic ignition advance angle through current speed and throttle open valve. Integrated air pressure and temperature sensor is used to save space. In order to start the engine at different temperature conditions successfully, a body temperature sensor should be installed for obtaining the engine body temperature information to correct ignition advance angle.

ECU. ECU is the core of ignition control system, which directly affects the performance and effectiveness of system control accuracy. Freescale16 bit microprocessor MC9S12XEP100 is chosen as the main chip.

Ignition control system should control high power transistor or FET on and off status to achieve driving output, driving chips and auxiliary circuit are generally used to achieve control function. MC33812 chip is chosen to control ignition pre-driver, the chip can directly drive the ignition coil to work by driving an external transistor. Fig.2 shows the circuit schematic diagram for MC33812, which is connected directly to the main chip SPI port through the serial input and output ports, sending and receiving commands. Because of low-side driving is adopted in the system to control external transistor, IGNOUTL side is used to control power transistor on and off.

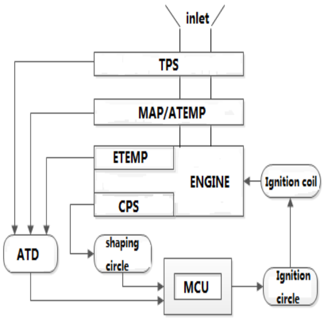

Fig.1 System layout diagram

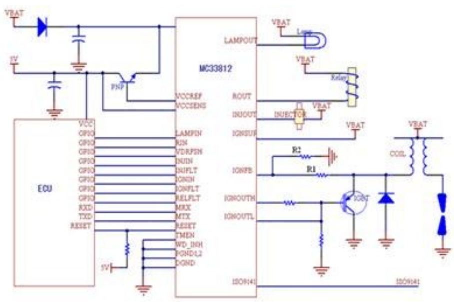

Fig.2 MC33812 connection diagram

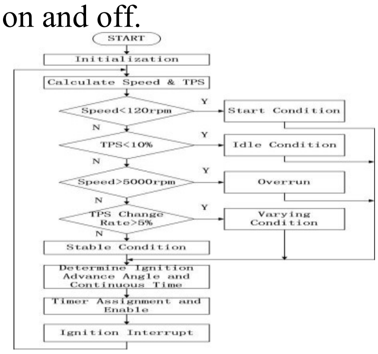

Fig.3 Main program flowchart

Actuators. Seen from Fig.1, actuators consist of CDI, ignition coils and spark plug.

No advance angle DC-CDI is adopted, which has no adjustment function, will be directly controlled by the ECU. Ignition coil is to increase voltage to 25,000 volts above. Spark ignition coil is to receive and load voltage from ignition coils, then breakdown the air between two poles and ignite the combustible gas in the cylinder.

Software Design. Data calculating and processing work is realized by software, which consists of conditions determining, output signals control and data storage and calculate.

Program Design Process. Fig.3 shows the main program execution flow, system first enters initialization after power-up, then complete conditions determination and timer enable work. Conditions are mainly determined based on current throttle open degree (TPS) and current engine speed (Speed).Fig.4 is ignition driving interrupt process flow, which is to achieve ignition control signal output, including data query, correct and timer enable.

As the Fig.5 shows the ignition waveforms of speed at 2000r/min, ignition advance angle is 15°CA. (1) and (2) represent the ignition spark angle and ignition advance angle. As shows, the ignition signal is triggered after ECU received the trigger signal for an angle delay, more over, the two signals are both at the top dead center before.

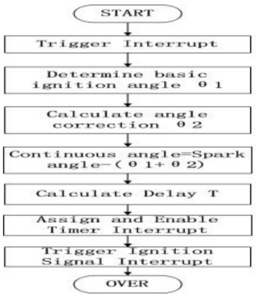

Fig.4 Ignition driving flowchart

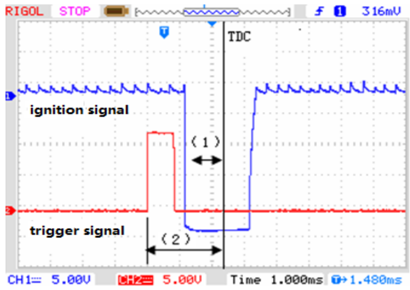

Fig.5 Ignition driving waveform

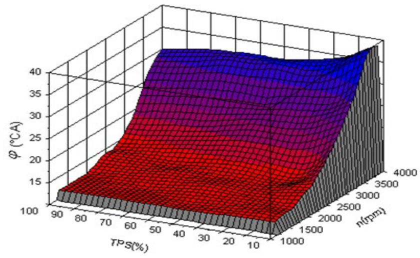

Fig.6 Basic ignition advance angle MAP

Data storage and read. Engine operation has significant nonlinear and time-varying characteristics, precise mathematical model is not fit for real-time control. Therefore, associated operation data are got by checking MAP table in the system. Pre-calibrated data are stored in read-only memory micro-controller(ROM) or erasable programmable read-only memory (EEPROM), program will copy the MAP data to initialize the random access memory (RAM). The program reads the data in RAM when system is running.

Main correction parameters. Correction parameters control strategy can be broadly divided into correction coefficient method and correction amount method. The latter is adopted in the system, basic amount add correction amount calculated through formula will obtain the required value.

Ignition advance angle correction. Lower engine body temperature yields slower combustion speed, due to starting concentration, mixed gas concentration will become larger [3]. In order to make the engine get good start performance, ignition advance angle correction is needed based on engine body temperature. (1) is the empirical correction formula for ignition advance angle.

$$M\_engine=-0.125\times T\_engine+7.5 \qquad (1)$$

M_engine is correction amount after calculating, T_engine is body temperature. After starting, as T_engine goes high, correction amount will be small.

Ignition continuous angle correction. When supply voltage is too low, due to lack of energy, misfire or abnormal ignition phenomenon will appear. To this end, ignition continuous angle should be corrected according to battery voltage. (2) is correction formula.

$$M\_dwell=-0.8\times V\_bat+9.6 \qquad (2)$$

M_dwell is correction amount, V_bat is battery voltage, ranging from 10V to 14V, if battery voltage is out of the range, the system will ignite abnormally and alarm.

Experimental results and analysis

A small gasoline engine 168F was chosen as study object. In order to cover all engine operating conditions as well as ECU storage ability and computing power, MAP, respectively, data are set according to speed and load conditions 17 and 10 points. According to emission, power, economy requirements, ignition advance angle MAP is set based on the rule of weighting method, the formula as shown in Equation 3.

$$\psi_i=\psi_{ji}\omega_j+\omega_{pi}\psi_p+\omega_{di}\psi_d \qquad (3)$$

i is an arbitrary point in basic ignition advance angle MAP, ω_j , ψ_p ,ψ_d are economic best, emission best, power best ignition advance angles in this operating condition. ψ_{ji},ω_{pi},ω_{di} are weight coefficient determined by weight of each conditions, ψ_i is final optimum ignition advance angle calculated for any operating condition.

Seen from Fig.6, optimized basic ignition advance angle changes in pace with throttle open degree and engine speed. While load is constant, higher engine speed yields bigger ignition advance angle, as the speed increases, combustion process time required is shortened, but the crank angle of combustion process increases, so ignition timing will be relatively early. While speed is constant, ignition advance angle decreases as load increases, this is because larger load yields mixture thicker, shorter ignition delay period, increasing flame spread rate.

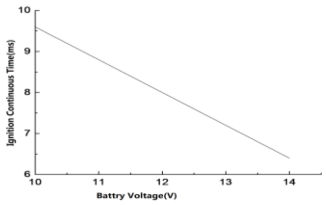

Fig.7 Ignition duration correction curve

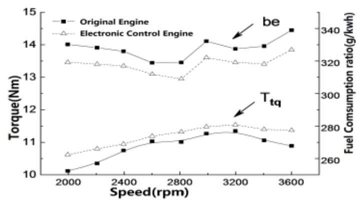

Fig.8 Torque and Fuel Curves

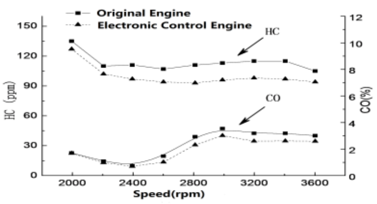

Fig.9 Emission contrast curve

The relationship between ignition continuous angle and battery voltage is shown in Fig.7, program will determine final ignition continuous angle by conversion relationship.

Fig.8 is fuel consumption and torque comparison of original engine and electric control system assembled engine at full-load condition, the data show that maximum torque increased by about 3% at different speed after the system assembled. This is because ignition advance angle can vary with engine load and operating conditions, while adjustment range increases. Original ignition advance angle ranges from 15°CA to 35°CA, while the angle of new system are not subject to the limitation, calibrated ignition advance angle ranges from 12°CA to 39°CA. Meanwhile, fuel consumption also has been reduced, obviously at low speed or a little more, this is because original ignition advance angle is more closer to the optimum one under heavy load, high-speed conditions.

Fig.9 is emission data comparison at full load condition. HC and CO emissions are both reduced with different degrees at rotational speed, indicating that ignition control accuracy improves after using this new system, so that combustion condition is optimized. Among them, the optimizing effect is more obvious under high speed, not only to original ignition advance angle is close to the optimum value, gas mixture is easy to combust completely and the emission amount is relatively stable.

Through above comparative analysis, the ignition advance angle can vary with engine speed and load changes in real time after using this electronically controlled ignition system, which ensure engine can get the best ignition performance in all conditions, so that gasoline power, economy, emission performance have been significantly improved.

Conclusion

The results shows that precise control of ignition advance angle and continuous angle are achieved after using the electronically controlled ignition system designed in paper, power, economy and emission performance have been improved significantly. The system is reliable over entire operating range, fully embodies the advantages of electronic control technology, but also demonstrate reasonableness of the system design and effectiveness of the control method.

Acknowledgment

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