Research and Development of Gasoline Direct Injection Image Acquisition System

Xiao ZHOU*, Xia WU and Jin-He CHEN

Ruian Quality and Technical Supervision and Testing Center Zhejiang, China

*Corresponding author

Keywords: Fuel Injector, Spray form, Photoelectric sensors, Image acquisition.

Abstract. Both industry standards and international standards in the field of automobiles recommend the image test method to detect the spray performance of the fuel injector. It is necessary to accurately determine the time when the fuel injector starts spraying and capture the spray image at the standard time for analysis. An injector spray image acquisition system based on photoelectric detection technology is proposed. The infrared photoelectric sensor is used to determine the initial starting time of the injector. The FPGA chip receives the trigger signal of the photoelectric sensor and then sends driving pulses to the industrial camera in the external trigger acquisition mode to realize spray image acquisition. Then, it is transmitted to the upper computer through gigabit network interface for subsequent image processing. The experimental results show that the system has stable performance and high quality of collected images, fully meets the high precision requirements of spray detection, and can be extended to droplet velocity measurement and other fields.

Introduction

SAEJ 2715-2007 “Gasoline Fuel Injector Spray Measurement and Characterization” requires that for Gasoline Direct Injection (GDI) is analyzed by taking the image delayed by 1.5 ms after the injection start time (SOF, Start of Fuel) of the fuel injector as the standard image (the accuracy requirement is ±0.01 ms). Therefore, how to accurately obtain the injection start time of the fuel injector is the key to obtain the standard spray image, which is of great significance to the spray pattern detection of the fuel injector [1-3]. In this paper, a method of GDI spray image acquisition using photoelectric sensor is proposed. At the moment when the fuel injector is out of oil, the level of the sensor output will flip, triggering FP-GA control chip to drive the camera to acquire the required standard spray image. The sensor is easy to install and operate, and the response speed of the photoelectric sensor is extremely fast, reaching ns level, thus ensuring the accuracy of image acquisition and laying a foundation for subsequent image processing.

Design of Overall System Structure

As shown in fig. 1. The system structure of this paper mainly includes three parts: fuel injector drive module, photoelectron detection module and image acquisition module. The driving module comprises a driving controller and a driving circuit, and the controller drives the fuel injector to work according to parameters set by upper computer software; The photoelectric detection module consists of an infrared photoelectric sensor and a fixed bracket, and is responsible for accurately detecting SOF time of the fuel injector; The image acquisition module consists of an FPGA-controlled chip industrial camera and a light source, and starts collecting spray images after receiving a trigger signal of a photoelectric sensor.
**Fuel Injector Drive Module**

The fuel injector adopts a peak holding current type driving circuit, and the driving circuit supplies the fuel injector with a certain electric pressure until reaching a predetermined current peak value so as to accelerate the opening of the injection. In order to minimize the instability when the injector is fully opened, the characteristics of the injector and the driver should be matched to ensure that peak conversion does not occur until the injector is fully opened. Then the current drops and stays at a lower value to ensure the duration of the injection pulse width. When the fuel injector receives the power-off signal, the current drops to a lower value, which reduces the residual magnetism in the fuel injector, thus accelerating the fuel injector to close.\[4, 6\]

The injector drive controller selects the EC3200DV24_12V_02 electronic control unit and is equipped with the operating software ECTEK Calibration System V2. As a control unit, ECU is composed of microprocessor, memory, input/output interface, analog-to-digital converter and large-scale integrated circuits such as shaping and driving. The upper computer communicates with ECU through USBCAN bus, and the calibration variable configuration and injection parameter control of injection current can be completed in ECTEK Calibration system V2, and the configured injection parameters of the injector are downloaded to ECU, which drives the injector to start working.\[7-8\].

**Photoelectric Detection Module**

Photoelectric sensor is a key part of the system and has very high requirements on its performance parameters. On the one hand, the sensor must be sensitive to spray and its response time is extremely short. On the other hand, spray detection requires multiple and long-term spraying, and the photoelectric sensor must ensure stable performance and can work continuously for a long time.\[9-10\].

According to the characteristics of GDI, such as transparent spray and small particle size, after many experiments, Omron E3Z-D82 diffuse reflection sensor is selected for detection. It has good response to transparent tiny objects, working voltage is 12 ~ 24 V, luminous wavelength is 860 nm, and detection distance is 1 ~ 50 cm. One side of the sensor is provided with a working stability indicator lamp and an adjusting hole for adjusting sensitivity. The other side is provided with a light projecting part and a light receiving part which are arranged in parallel, the light projecting part continuously emits infrared light, and when the fuel injector is closed, the light does not return to the light receiving part; If the spray is started, the reflected light is reflected when the spray passes through the detection surface. After the light receiving part receives the reflected light, the light receiving amount increases to a constant value, the internal circuit is gated, and the black output line outputs a low level.

**Image Acquisition Module**

The image acquisition module consists of FPGA chip, industrial camera and area array light source. The FPGA development platform uses black gold development board, and the chip is EP4CE15F17C8 chip. The operating frequency is 50MHz and the output voltage is 3.3V. The synchronous delay drive signal required by the camera is output through programming such as the
quartus II programming software. The image acquisition camera uses a megapixel basler aca1300-60gm and 1000 Meganet camera, resolution 1280 pixels * 1024 pixels. It is also equipped with a lens with high quality and minimum distortion. It relies on a lower aperture number to provide sufficient light collection. The light source is an LED area array light source with high brightness and large enough luminous area to meet the needs of the field of view.

Backlight imaging is adopted to collect spray images. Backlight imaging method is suitable for imaging with relatively uniform spraying, and it is easy to determine the spraying boundary. As shown in fig. 2, the camera and light source are respectively placed on both sides of the fuel injector, facilitating clear images with bright background and dark foreground. After the light path is built, adjust the camera's field of view so that the spray takes up almost the entire image.

Camera works in falling edge external trigger mode, with 12 I/O digital interfaces, and interfaces input 1 and input Gnd are respectively used for driving signals and connecting ground wires. After the FPGA detects the trigger signal at the output of the sensor processed by the voltage amplifier, the trigger pulse is input to the camera with a synchronous delay of 1.5ms. Since the effective trigger voltage range outside the camera is 4-24V, while the real output voltage of the FPGA chip is only 3.3V, a voltage amplification circuit needs to be added at the output of the FPGA, and LM358 type operational amplifier is selected to build the circuit to raise the camera drive signal to 5V. The camera acquisition control sequence is shown in fig. 3. The fuel injector emits a pulse of 1.5ms with a period of 50ms when the fuel injector is turned on, the sensor jumps from a low level to a high level. The FPGA triggers on the rising edge of the sensor response pulse, delaying light acquisition by 1.5ms. The exposure time is 20 μs. In this way, the camera can synchronously delay exposure for 1.5ms and output a spray image at standard time for each injection by the injector. The camera drive signal exposes the camera on the rising edge of the drive pulse.
Experimental Results and Analysis

The experimental platform as shown in fig. 4 is built. The working voltage of the sensor is 12V, the injection pulse of the fuel injector is 1.5ms, and the period is 50ms, continuous injection is carried out for a total of 500 times, the driving camera collects spray images. Finally, 500 spray images were collected and one image was randomly selected, as shown in fig. 5.

![Figure 4. Actual work of the experimental platform.](image1)
![Figure 5. Standard spray images.](image2)

From the experimental results, it can be seen that the camera collects and outputs a spray image every time the injector injects, and the spray shape in each image is basically the same, indicating that the system can capture the spray standard image quickly and accurately, with clear imaging and obvious difference of spray boundary, which can be used for subsequent image processing and calculation of spray characteristic parameters.

Conclusion

Infrared photoelectric sensors have many unique properties and have been applied in many fields. The system described in this paper uses infrared light emitting and receiving integrated diffuse reflection sensor E3Z-D82 to detect the initial injection timing of GDI spray. It has stable performance and convenient installation. Combined with industrial cameras, it can quickly collect the required standard spray images. This method has very high accuracy and greatly reduces the detection cost. It has certain reference value for the field of velocity measurement and distance measurement of high-speed fluid.

References

[1] China National Standardization Administration. Technical Article of Solenoid Fuel Injector Assembly for Gasoline Engines: GB/T 25362-2010 [S]. Beijing: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, 2010: 11.

[2] China National Standardization Administration. Technical Methods for Solenoid Injector Assemblies for Gasoline Engines: GB/T 25363-2010 [S]. Beijing: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, 2010: 11.

[3] Society of Automotive Engineers. Gasoline Fuel Injector Spray Measurement and Characterization JSAE J 2715—2007 [S]. SAE Publication, 2007: 3.

[4] Huang Dou. Study on Driving Circuit and Spray Characteristics of GDI Gasoline Engine Injector [D]. Wuhan: China University of Science and Technology, 2011

[5] Chen Shen, Li Yun Qing, Wang Defu. Design of GDI Injector Driver Circuit Based on L9707 Chip and Experimental Verification [J]. Internal Combustion Engine and Power Unit, 2010(1): 1-6

[6] Hu Chunming, Guo Shouchang, Cui Runlong, et al. Development and Optimization of Fuel Injector Drive Module for Direct Injection Gasoline Engine [J]. Internal Combustion Engine Engineering, 2013 35 (3): 83-88.
[7] Qi Xiaobin, Zheng Tong. Design and Implementation of ECU Measurement and Control Software Based on CAN Bus [J] aviation computing technology, 2011, 41 (2): 128-131.

[8] Soo HL, Park T W, Moon K H, et al. The articulated vehicle dynamic analysis using the AWS (All Wheel Steering) ECU (Electronic Control Unit) test [J]. Journal of Mechanical Science and Technology, 2009, 3 (4): 923-926.

[9] Li H S, Lei Z Y. Study and analysis on a new optical detection design method for photoelectric detection target [J]. Sensor Review, 2013, 33(4): 315-322.

[10] Cai Huaiyu, Wang Wentao, Sun Qiushi, et al. Reflective Light Screen Photoelectricity for High Speed Object Velocity Measurement Performance Research [J]. Sensors and Microsystems, 2011, 30 (5): 27.