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Study on a New Type of Electric-controlled Engine Fuel Consumption Meter Based on Volume Method

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Abstract: At present study on the testing methods and instruments for vehicles' fuel consumption is still not perfect. It still can't provide a rapid and accurate measuring method and instrument. A new type of fuel consumption meter structure is developed which used two small containers to relay to supply the engine and realizes oil consumption measuring by detecting the real-time liquid level in the containers. Photoelectric sensors and a chip microcomputer are used to realize transient detection. Its structure and principle are analyzed. The system of its hardware and software of the electric-controlling system are designed. Some key components are selected and the process of exhausting, starting and measuring are designed. Precision test of the system is performed, and the result shows the accuracy of the meter in the range of 800 ml is 0.1 %, which meets the requirements and the feasibility of the structure is verified. Finally the main influencing factors are analyzed. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Fuel Consumption Meter, Volume Method, Measuring Precision, Photoelectric Sensors, Chip Microcomputer.

1. Introduction

Since the fuel consumption is an important evaluation index of the vehicle's fuel economy, many domestic and foreign scholars have made a great deal of research on the measuring method of it [1]. The method which measures fuel consumption by directly measuring the fuel volume consumed is called Volume Method which uses different forms of fuel flow sensors to measure the fuel volume consumed [2-4]. At present, the forms of fuel flow sensors mainly consist of rotary pistons, waist wheels, elliptic gears, helical rotors etc. [5-6].

Volume Method is classified into 2 types [7]. One method is to measure fuel consumption by calculating the time consuming fuel of fixed volume, the other by calculating fuel volume on fixed time. The former method is often applied on engine testing bench, because of its principle, it could not be used to measure transient fuel consumption. The latter one is also called capacity method and could be used to measure transient and instantaneous fuel consumption [8-9].

This paper aims to design a new type of fuel consumption meter, which is based on Volume Method but abolishes traditional flow sensors often adopted by Volume Method. It also has a relative high accuracy and could test the transient fuel consumption to a certain degree.

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2. Structure Design

2.1. Scheme Design

The scheme of new type of fuel consumption meter is as follows:

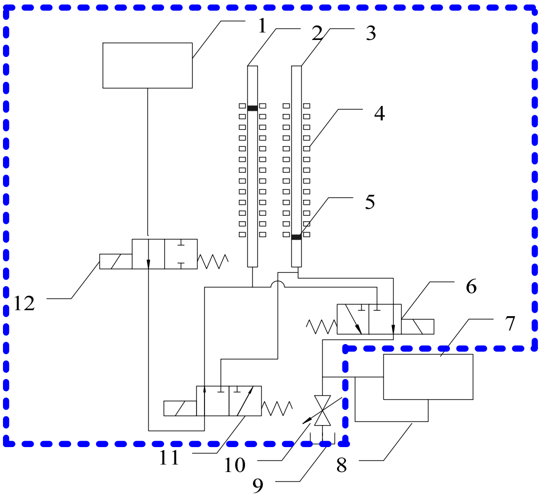
1) Two small measuring burettes are used to provide fuel to an engine alternatively. When the liquid level of one measuring burette supplying fuel drops to a setting position, the other measuring burette is switched to supply fuel and the burette out of service is charged. So the fuel is fed to the engine alternatively.

2) Two sets of photoelectric sensor are employed to real-time monitor the liquid level of fuel of two measuring burettes and convert them into real-time signals or real-time fuel consumption.

Photoelectric sensors are made up of light-emitting diodes and phototransistors. Phototransistors are used to detect infrared ray emitted by light-emitting diodes and if infrared ray is blocked by shelters, phototransistors would detect the signal. The light-proof float placed in burettes could move up and down with the liquid. When the float passed through the monitoring point, the infrared ray is blocked, so the position of the liquid level could be measured reliably [10].

2.2. Structure Design

As shown in Fig. 1, it has two Alkali burettes of 50 ml to relay to supply fuel to an engine, and two sets of photoelectric sensors to detect the liquid level in the burettes. Electromagnetic valves 6, 11, 12 controlled by a chip microcomputer are used to adjust the sequence of supplying and charging.



1 - external fuel tank; 2 - Alkali burette; 3 - Alkali burette; 4 - photoelectric sensors; 5 - Float (light-proof);
6 - reversing valve; 7 - engine; 8 - engine fuel return pipe;
9 - tank; 10 - throttling valve; 11 - reversing valve;
12 - switch valve.

Fig. 1. Structure design.

In addition, this fuel consumption meter requires the speed of fuel charging higher than the speed of supplying, and it can be realized by placing the external fuel tank high.

2.3. Function Design

When the system is under preparation stage, that is, before an engine starts, exhaust air in the pipe.

Press “start” button, the system is in working mode, the engine could be started.

Press “measure” button, the system starts to record and display real-time fuel consumption and its pulse signals are outputted to a secondary instrument.

Press “ending” button, the fuel consumption meter continues to supply fuel to the engine and display the final fuel consumption.

Press “continue” button, the fuel consumption meter display clears and restarts counting and real-time fuel consumption pulse signals are outputted to a secondary instrument.

3. Hardware Design

3.1. Systematic Diagram of Electric-Controlling System

Based the function of fuel consumption meter, the structure of controllers is as shown in Fig. 2. It consists of a chip microcomputer, detection circuit of liquid level, controlling circuit of electromagnetic valves, key input, digitron display. The detection circuit of liquid level is divided into upper, lower and middle liquid detection.

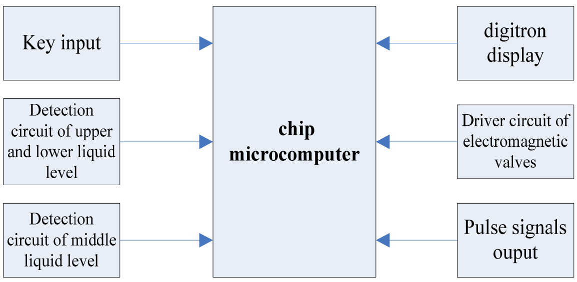


Fig. 2. Systematic diagram of electric-controlling system.

A chip microcomputer determine if charging or supplying fuel judging from the signals of the upper or lower liquid level of burettes, then fuel consumption are calculated depending on the signals of the upper/lower and middle liquid level of burettes. The value of fuel consumption is displayed through digitron monitor and pulse signals of fuel consumption are outputted to a secondary instrument.

3.2. Electromagnetic Valves Selection

Adopt the SMC electromagnetic valve VX332.2 and its response time is 16.7 ms which can meet the requirement of the device.

A field-effect tube is employed as a driving tube. When electromagnetic valves are closed, both ends of electromagnetic valve coil would produce a reverse voltage influencing circuits, so freewheeling diodes are used to eliminate the induction current. The controlling circuit of electromagnetic valves is shown in Fig. 3.

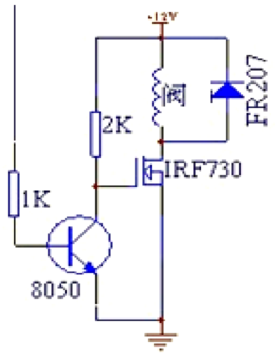


Fig. 3. The controlling circuit of electromagnetic valves.

3.3. Circuit of Photoelectric Sensors

Photoelectric sensors of 0S25B10 are used to detect the liquid level of burettes. A float (light-proof) would ascend or descend with the liquid level. When the liquid passes through photoelectric sensors, the float would block receiving terminal, a pulse signal is outputted. The comparator of LM358P converts the pulse signal to high power pulse signal of 5 V. The circuit of photoelectric sensors is shown in Fig. 4.

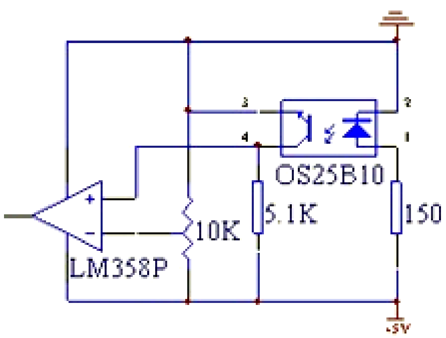


Fig. 4. Circuit of photoelectric sensors.

Due to the number of photoelectric sensors beyond the resource of pins, so OR-gate of 74HC32 is employed to collect pulse signals transformed by comparer LM358PZ and then sent to the chip microcomputer to be processed. The Signal acquisition circuit of photoelectric sensors is shown in Fig. 5.

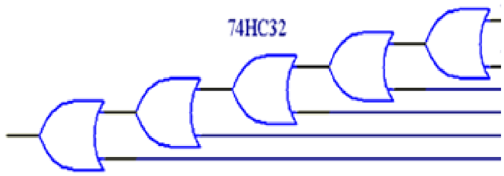


Fig. 5. Signal acquisition of photoelectric sensors.

3.4. Single Chip Selection

Use the Microchip's PIC18F4520 microcontroller as the main control chip. It has two external interrupts, 1 RB port interrupt, and its timer T0 can also construct an external interrupt, which can satisfy the requirement of application. The list of PIC18F4520 chip is as shown in Table 1.

Table 1. List of PIC18F4520 chip.

Items	Parameters
Core	PIC 8-bit RISC
Voltage	2.0-5.5 V
Frequency	20 MHz Max
Storage resource	32 K Flash, 1536 B RAM, 256 B EEPROM
I/O	33
Interface	1 × MSSP (SPI/I2C), 1 × A/E/UART, 2 × PWM, 8 × ADC
Enclosure	DIP40

3.5. Design of Electric Source Circuit

Switching power supply S-75-12 of 72 W is applied to be a driving power, whose outputting voltage is 12 V; the electric source of 5 V needed for the chip microcomputer is provided by voltage-regulator tube L7805. The circuit is shown in Fig. 6.

4. Software Design

4.1. Exhausting the Air in the Fuel Pipe

When the system is in the preparation stage, namely before starting the engine, the air in the oil circuit should be exhausted. This work can be easily accomplished with the throttling valve 10 (as shown in Fig. 1).

The concrete process is shown as follows: turn on the system first, and then manually control the throttling valve 10. In this way, the fuel in the external tank 1 (as shown in Fig. 1) will flow into burettes and fuel tank 9 (as shown in Fig. 1). After several circles the air can be easily squeezed. The detailed flowchart of exhausting the air in the fuel pipe is shown in Fig. 7.

4.2. Starting

When pressing "start" button, the engine can be started. First, the burette 3 (as shown in Fig. 1) supplies fuel, at the same time the burette 2 (as shown in Fig. 1) is charged. When the liquid level of the burette 3 descends to the lowest point, switch to the burette 2 supplying and the burette 3 is charged simultaneously. The procedure is shown in Fig. 8.

4.3. Measuring

When pressing "measure" key, the chip microcomputer collects pulse signals of photoelectric tubes real-time and transforms it to the signal of fuel consumption and display.

When pressing "ending" key, the fuel consumption continues to supply the engine and displays the final fuel consumption.

The designed software flow is shown in Fig. 9.

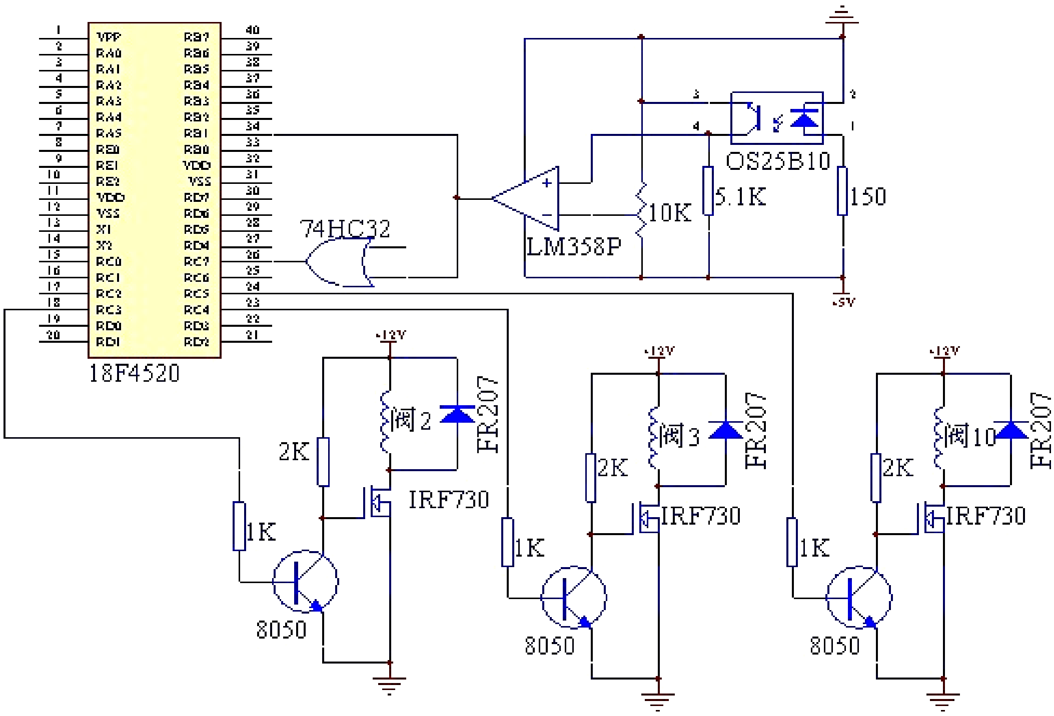


Fig. 6. Design of the control system's circuit.

5. Precision Test of the System

Use a 1000 ml cylinder to test the system's precision, as shown in Fig. 10.

Ten groups of photoelectric sensors between the distance of every 2 ml in two burettes are evenly arranged. During the fuel consumption meter operating, the liquid level of every burette moves between photoelectric sensors, and when it passes through one photoelectric sensor, a pulse signal is outputted. If the liquid level of one burette moves from the bottom to the highest position, ten pulse signals are exported. In order to get the corresponding oil consumption for each pulse, the process of calibration need to be performed for outputting pulse of the fuel consumption meter. At the same time, in order to analyze the precision of the fuel consumption meter, the consistency of the corresponding fuel consumption for each pulse should be examined.

The principle of precision calibration are stated as follows: the degree of opening of throttling valve 3 (as shown in Fig. 1) is adjusted to control supplying speed of fuel consumption meter to the cylinder, the beginning and termination of calibration are controlled by switching valve 4 (as shown in Fig. 1). The liquid level could be obtained by observing scale on the cylinder and total number of pulse or total fuel consumption could be read by a LED monitor.

The self-made fuel consumption meter and its calibration system are shown in Fig. 11.

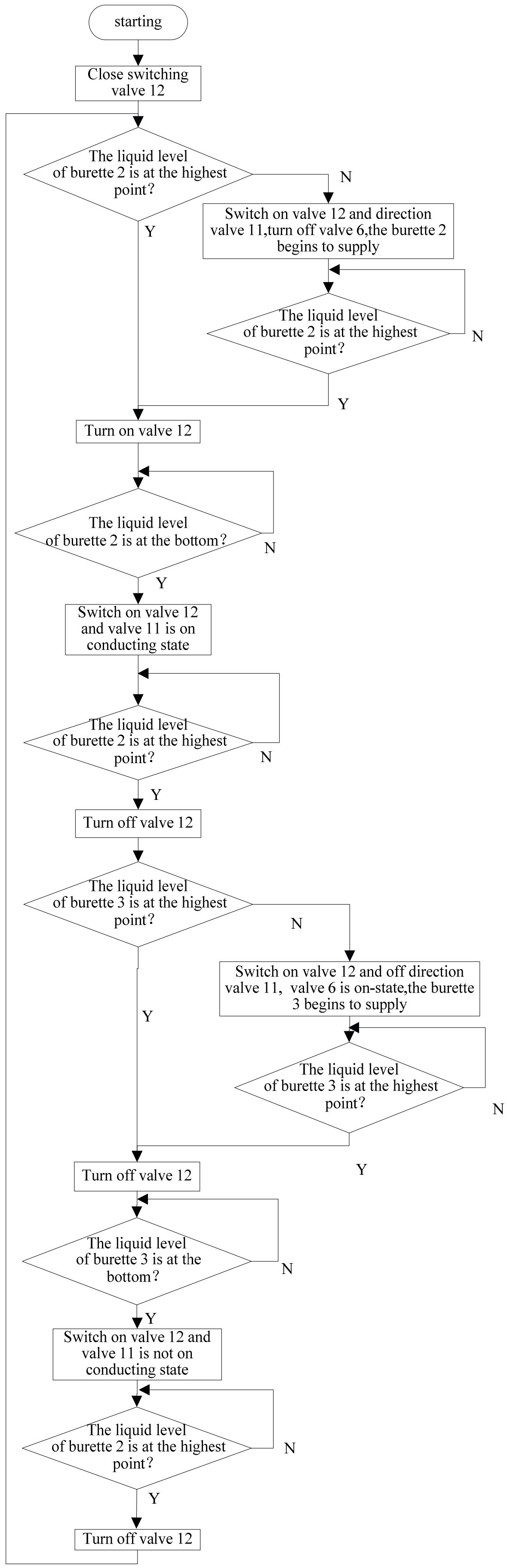


Fig. 7. Flowchart of exhausting the air in the fuel pipe.

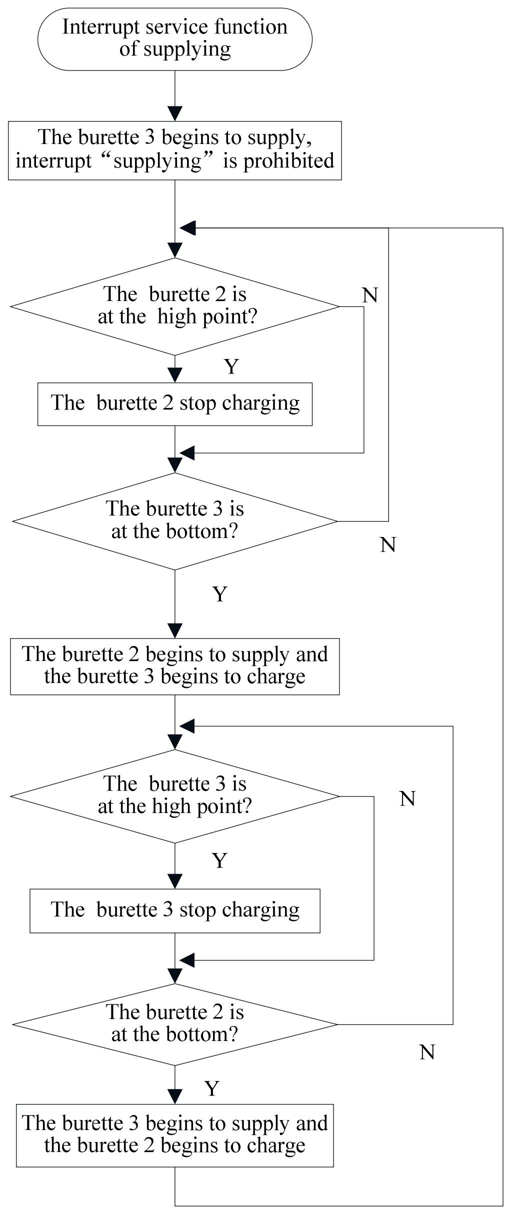


Fig. 8. Flowchart of starting.

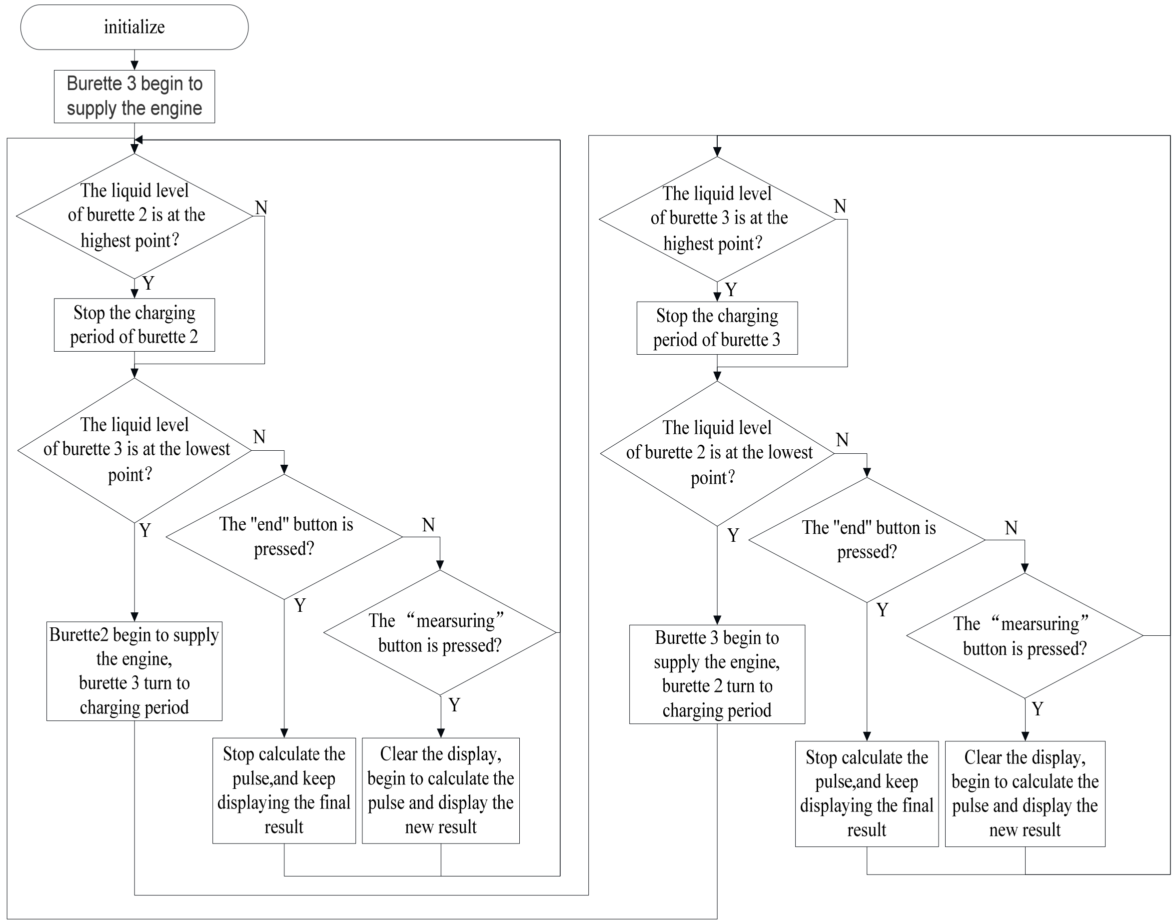
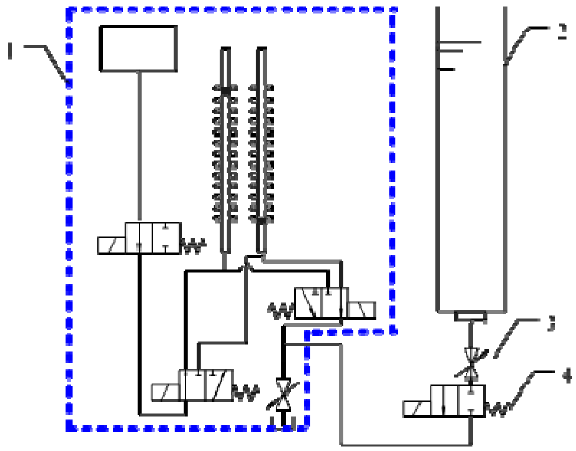


Fig. 9. Flowchart of measuring.



1 - self-made fuel consumption meter;
2 - cylinder of 1000 ml; 3 - throttling valve;
4 - switching valve.

Fig. 10. Chart of precision calibration bench.

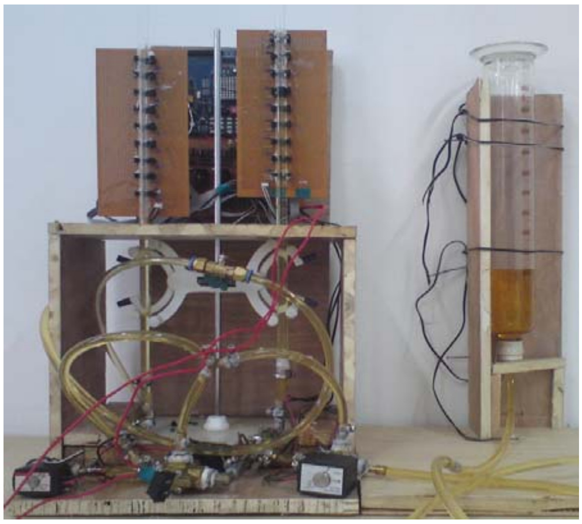


Fig. 11. Self-made fuel consumption meter and calibration device.

Supple the cylinder in the fixed volume mode, and the supplying speed is controlled by throttling valve 3 randomly, the volume of the cylinder is 800 ml. The equivalent pulse of fuel consumption is defined as:

$$p = n / l , \tag{1}$$

where n is the number of pulses, l is the volume.

The testing results are shown as Table 2.

Analysis on the testing results of calibration is shown in Table 3.

The result shows the accuracy of the meter in the range of 800 ml is 0.1 %.

Table 2. Testing results of calibration.

n (Number of times)	P(/ml)	Δn	Δp	$\frac{\Delta n}{\bar{n}}$	$\frac{\Delta p}{\bar{p}}$
400	0.500	0.8	0.0013	0.20 %	0.20 %
400	0.500	0.8	0.0013	0.20 %	0.20 %
399	0.498	-0.2	0	-0.05 %	-0.05 %
399	0.498	-0.2	0	-0.05 %	-0.05 %
400	0.500	0.8	0.0013	0.20 %	0.20 %
398	0.497	-1.2	-0.0015	-0.30 %	-0.30 %
399	0.498	-0.2	0	-0.05 %	-0.05 %
400	0.500	0.8	0.0013	0.20 %	0.20 %
398	0.497	-1.2	-0.0015	-0.30 %	-0.30 %
399	0.498	-0.2	0	-0.05 %	-0.05 %

Table 3. Analysis on testing results of calibration.

	n	p
Arithmetic mean	$\bar{n} = 399.2$	$\bar{p} = 0.4987$
Maximum absolute error	0.8	0.0015
Maximum relative error	-0.30 %	-0.30 %
Standard deviation	0.77	0.001

The main influencing factors are analyzed as below:

1) Using photoelectric sensors to detect the fuel level can't realize the fuel level's continuous detection, and it would cause 2 pulses' error at most. This error can be reduced by placing as many sensors along the burette as possible, and the longer the distance of testing (such as the measurement of fuel consumption per hundred kilometers), the smaller the influence of these 2 pulses error.

2) The device adopts the SMC electromagnetic valve VX33 whose response time is 16.7 ms, thus, the error caused by electromagnetic valve's response time is small enough to be ignored.

3) Error caused by the system's processing and assembly accuracy. This error can be reduced by improving the system's processing precision.

6. Limitation Analysis of the Fuel Consumption Meter

After a period of trial, it is proven that the method mentioned above is a good way to measure an engine fuel consumption under an engine test bench which has the advantage of convenient use and reliable operation.

But for vehicles road test, it still exists a certain degree of limitation. First of all, the fuel consumption meter needs to be concatenated in fuel pipes, which means a cumbersome modification. Secondly, in the road test, road conditions such as bumping would influence the float in burettes, when it shakes beyond the setting parameters of the hardware and software, the corresponding error would emerge.

In addition, for an engine with large amount of returning fuel, the fuel-returning pipe couldn't be connected to fuel inlet pipe directly. Because under unstable working conditions, large fluctuation of the amount of fuel-returning and fuel-returning pressure would emerge, which would cause interference for the operation of the system, and real-time fuel consumption cannot be measured. To solve the problem, the output of the fuel consumption meter should connect serially with one float chamber to eliminate the oil return interference.

Therefore, the fuel consumption meter is the most suitable for test bench and road test of fuel consumption, which can guarantee the accuracy of measurement.

7. Conclusions

After a period of testing, it was proved that in static testing conditions, the system can meet the measurement of engine fuel consumption well. Compared with other types of fuel consumption meters based on Volume Method, this fuel consumption meter without using flow sensor has obvious economic benefits. And the feasibility of the structure and the accuracy is verified.

Acknowledgments

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