

## Study And Calibration on the Intake Flow Control of Multipoint Injection Gas Engine

Huang Mintao<sup>1\*</sup>, Wu Changshui<sup>2</sup>, Feng Chen<sup>3</sup>, Wang Zhibin<sup>4</sup>

(College of Automotive Engineering, Shanghai University of Engineering Science, China)

Corresponding Author: Huang Mintao

**ABSTRACT:** Engine ECU can achieve precise control of the throttle opening through the control strategy, which can precisely control the air flow rate. And the control precision of air flow rate determines the control accuracy of air-fuel ratio in the engine. So, it is vital to the precise calculation of the air flow. After the acquisition of steady state data by the engine testing, this paper calculates the air mass flow according to the flow characteristics of the injector, and then use throttle flow model to calculate and correct it. Finally we could obtain a formula which can accurately calculate the air mass flow of transient and steady state conditions. Using simulink to build the throttle flow model, so as to improve the air-fuel ratio control strategy module. During the calibration of engine ECU, avoid a lot of engine bench test was carried out on the fuel injection pulse-width MAP calibration. It has the vital significance of engine ECU calibration.

**Keywords :** Airflow; Air-fuel ratio; Gas engine

Date of Submission: 12-10-2017

Date of acceptance: 27-10-2017

### I. INTRODUCTION

The improvement and optimization of the engine's control strategy is carried out on the basis of the engine bench test, which is very important for the control of the air mass flow. The precise control of the quality of the air entering the cylinder directly affects the control of the air-fuel ratio, which is also an important part of the overall air-fuel ratio control<sup>[1]</sup>. By precisely controlling the electronic throttle opening to achieve precise control of the air mass flow, the appropriate amount of fuel is supplied according to the target air-fuel ratio. Therefore, selecting a suitable algorithm is critical to the calculation of engine air mass flow. This paper is based on a six-cylinder multi-point EFI gas engine ECU calibration project as the background. It is desirable to obtain a computational model that can accurately calculate the air mass flow to accommodate the control strategy of the multi-point EFI gas engine. Not only reduces the engine ECU calibration workload, but also improve the engine ECU calibration data accuracy.

### II. GET ACTUAL AIR MASS FLOW

In order to obtain the relevant calculation parameters, a multi-point EFI engine bench test was carried out. Using eddy current dynamometers, CANape online calibration tools, pressure sensors, temperature sensors and oxygen sensors.

**Table 1** Main Engine Parameters

| Name          | Parameters   |
|---------------|--------------|
| Intake method | Turbocharger |
| Type of fuel  | CNG          |
| Cylinders     | 6            |
| Displacement  | 7.8L         |
| Bore *Stroke  | 112*132mm    |
| Maximum power | 191kw        |

And then, we obtained a large number of engine bench test data through the engine bench test.

**Table 2** Engine Bench Test Data

| Air-fuel ratio | The pressure before the | Throttle | Intake air | Throttle | Injection |
|----------------|-------------------------|----------|------------|----------|-----------|
|----------------|-------------------------|----------|------------|----------|-----------|

\* Corresponding author.

E-mail addresses: hmintao@163.com

| rpm  |       | throttle (bar) | pressure (bar) | temperature (k) | opening % | pulse (ms) |
|------|-------|----------------|----------------|-----------------|-----------|------------|
| 900  | 20.83 | 1.04           | 0.71           | 315             | 16        | 2.7        |
| 900  | 16.56 | 1.34           | 1.28           | 308.2           | 60        | 6.5        |
| 900  | 21.88 | 1.27           | 1.04           | 313.5           | 23        | 4          |
| 1000 | 17.55 | 1.40           | 1.39           | 319.3           | 60        | 2.72       |
| 1000 | 20.36 | 1.05           | 0.75           | 312.6           | 18        | 6.48       |
| 1000 | 19.89 | 1.27           | 1.07           | 313             | 24        | 4.32       |
| 1300 | 20.83 | 1.05           | 0.66           | 305.4           | 19        | 2.3        |
| 1300 | 19.19 | 1.45           | 1.22           | 313.3           | 27        | 5.3        |
| 1500 | 20.83 | 1.06           | 0.66           | 320.4           | 20        | 2.4        |
| 1500 | 20.13 | 1.43           | 1.22           | 314.5           | 26        | 4.7        |
| 1700 | 20.01 | 1.11           | 0.76           | 317.4           | 24        | 2.8        |
| 1900 | 20.48 | 1.55           | 1.31           | 317.6           | 33        | 5.3        |

Before the air-fuel ratio control strategy has not been perfected, the engine bench calibration test is given by the man-made injection (gas) pulse width<sup>[2]</sup>. Since the engine is a six-cylinder multi-point EFI gas engine, six injectors are required to provide fuel for each cylinder. After the engine is converted into a multi-point EFI gas engine, the fuel is controlled by the injector of the control strategy. Therefore, according to the steady-state engine bench test data, according to the CANape interface display parameters, including the nozzle valve flow rate (injector flow characteristics is 16mg / ms), calculated steady state conditions per hour supply of natural gas , According to the air-fuel ratio, and then calculate the hourly air mass flow. The hourly fuel injection is calculated as:

$$Q = \frac{w \times v}{10^6} \times \frac{n}{120} \times 3600 \times 6$$

Among them:

$Q$  ---Hourly fuel injection (natural gas) mass flow

$w$  --Fuel injection pulse width

$v$  --Injector flow rate

$n$  --Engine speed

The fuel mass flow is multiplied by the corresponding air-fuel ratio to obtain air mass flow. The results are as follows:

**Table 3** Actual air mass flow

| rpm            | 900   | 1000  | 1000  | 1300  | 1300  | 1500  | 1500  | 1700  | 1700  | 1900  |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Air-fuel ratio | 20.83 | 20.36 | 19.89 | 20.83 | 19.19 | 20.83 | 20.13 | 19.43 | 19.43 | 20.48 |
| Air mass flow  | 145.8 | 159.5 | 247.5 | 179.3 | 380.8 | 215.9 | 408.6 | 274.3 | 542.4 | 593.8 |

### III. THROTTLE FLOW MODEL

The accuracy of the air flow rate of the ignition engine determines the control of the air-fuel ratio. Inaccurate control results in a decrease in engine power and economy, and an increase in harmful emissions<sup>[3]</sup>. The speed density method can only guarantee the accuracy of the air under steady-state conditions, but in the transient conditions, the use of speed density method will produce a lot of error. So the need to introduce an algorithm to meet the engine under any conditions of air mass flow calculation, and to ensure its accuracy. Using throttle flow model<sup>[4]</sup>. Consider entering the intake air flow from the throttle passageway. Because the accurate calculation of the air flow through the throttle valve is the need to establish a three-dimensional unsteady flow model, the complexity is too large, which can be simplified as a one-dimensional isentropic stable flow calculation<sup>[5]</sup>, throttle at the channel is also a simple change in the area of the circle The And taking into account the impact of other factors on the formula calculation results. It is desirable to find the relationship between the formula and the true value of the actual intake air volume and then correct it. Making the accuracy of the formula closer to the true value. Theoretically, the air mass flow equation at the throttle is described as:

$$m_a = A_{red} \cdot P_{thr} \cdot C_1 \cdot \psi$$

Among them:

$$A_{red} = \frac{\pi D^2}{4} (1 - \cos \alpha) \quad C_1 = \sqrt{\frac{2k}{(k-1) \cdot R_s T_{im}}}$$

$$\psi = \left(\frac{2}{k+1}\right)^{\frac{1}{k-1}} \sqrt{\frac{k-1}{k+1}} \cdot \frac{P_{im}}{P_{thr}} \leq 0.53 \quad \psi = \sqrt{\left(\frac{P_{im}}{P_{thr}}\right)^{\frac{2}{k}} - \left(\frac{P_{im}}{P_{thr}}\right)^{\frac{k+1}{k}}}, \frac{P_{im}}{P_{thr}} > 0.53$$

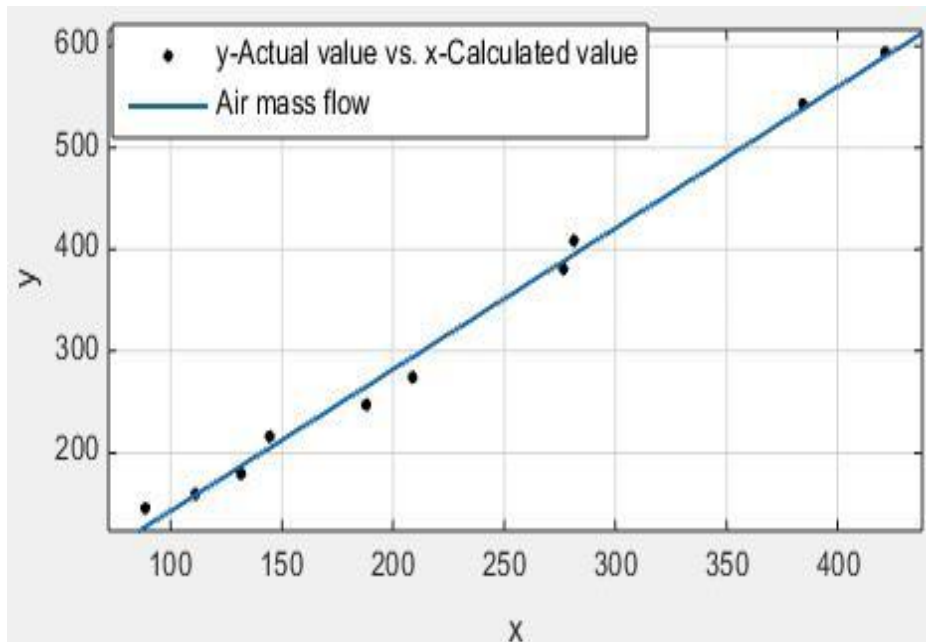
Where,  $D$  is the throttle diameter,  $k$  is the adiabatic index,  $R_s$  is air gas constant,  $P_{im}$ 、 $P_{thr}$  for the intake manifold (after the throttle), before the throttle pressure,  $T_{im}$  is the intake air temperature.

Table 2 in the engine bench test data into the formula, the results are as follows:

**Table 4** Theoretical calculation of air mass flow

| rpm            | 900   | 1000  | 1000  | 1300  | 1300  | 1500  | 1500  | 1700  | 1700  | 1900  |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Air-fuel ratio | 20.83 | 20.36 | 19.89 | 20.83 | 19.19 | 20.83 | 20.13 | 19.43 | 19.43 | 20.48 |
| Air mass flow  | 88.6  | 111.0 | 187.9 | 131.7 | 276.7 | 144.5 | 281.4 | 208.8 | 384.4 | 421.4 |

The calculated results of the throttle model and the actual air intake are fitted, and the following relationship exists:



**Figure 1** The relationship between the actual value and the calculated value

It can be seen from the figure that there is a linear relationship between the theoretical air mass flow and the actual mass flow. The fitted linear relationship is:

$$Q = a \cdot m_a + b$$

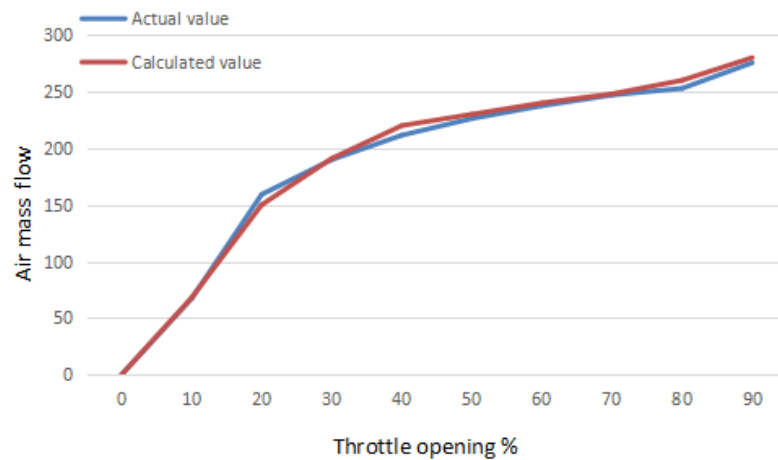
Where  $a$  and  $b$  are constants, according to the correlation analysis,  $a = 1.389$ ,  $b = 4.055$ . So the modified throttle model is expressed as:

$$Q = 1.389 \cdot m_a + 4.055$$

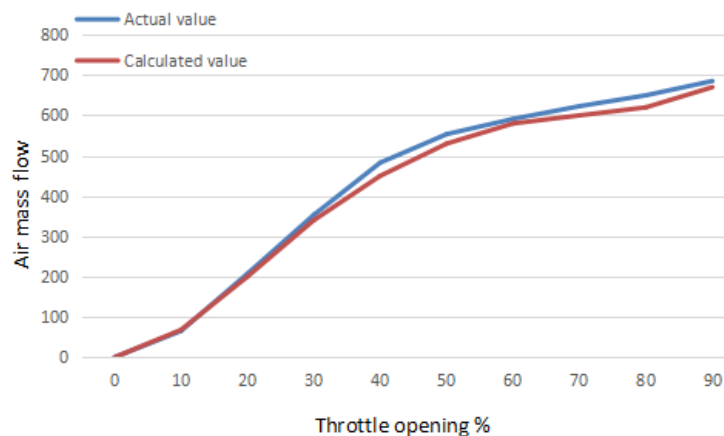
#### IV. ENGINE BENCH TEST TO VERIFY

The formula for calculating the air mass flow is calculated after the engine chooses some steady-state condition test data. In order to verify the accuracy and reliability of the formula, it is necessary to verify the bench test for any working conditions.

The actual air mass flow rate is compared with the calculated air mass flow rate according to the different throttle opening degrees by the gantry constant rotation torsional mode fixed speed 900rpm and 1800rpm. As shown below:



**Figure 2** Engine speed 900rpm



**Figure 3** Engine speed 1800rpm

According to the comparison, we can find that the calculated value of the modified formula is close to the actual value, thus verifying the feasibility of the formula..

## V. INFLUENCE OF THROTTLE MODEL ON ECU CALIBRATION

In the absence of a throttle model, the engine ECU calibration is required to perform a large number of engine bench tests to calibrate the MAP of the fuel injection pulse width, not only the workload is large, but also the accuracy of the calibration depends on the fineness of the bench test. Moreover, taking into account the car often run in the transition conditions, when the engine in the transition conditions, if the use of open-loop fuel injection control, the impact of air-fuel ratio is very large, oil and gas matching is difficult to achieve the best. And this also requires a large number of calibration tests for the engine ECU, which will undoubtedly increase the product development costs and cycles.

The air intake rate calculation model is set up by using Simulink to set the air-fuel ratio control part of the control strategy, which makes the air-fuel ratio control strategy part more perfect. When the engine is running in a certain situation, such as the start of the case, the use of open-loop control, ECU according to the engine of the sensor to calculate the amount of air, and then according to the target air-fuel ratio, the need to calculate the conditions Of the basic fuel injection, get the corresponding basic pulse width. When the air-fuel ratio is closed (such as idle and partial load conditions), the ECU calculates the amount of air under this condition, and then calculates the basic fuel injection amount according to the oxygen sensor signal. At this time, PI closed-loop control is implemented for the air- The fuel injection quantity is adjusted so that the actual air-

fuel ratio approaches the target air-fuel ratio, and when the condition is satisfied, the basic fuel injection amount under the working condition is obtained.

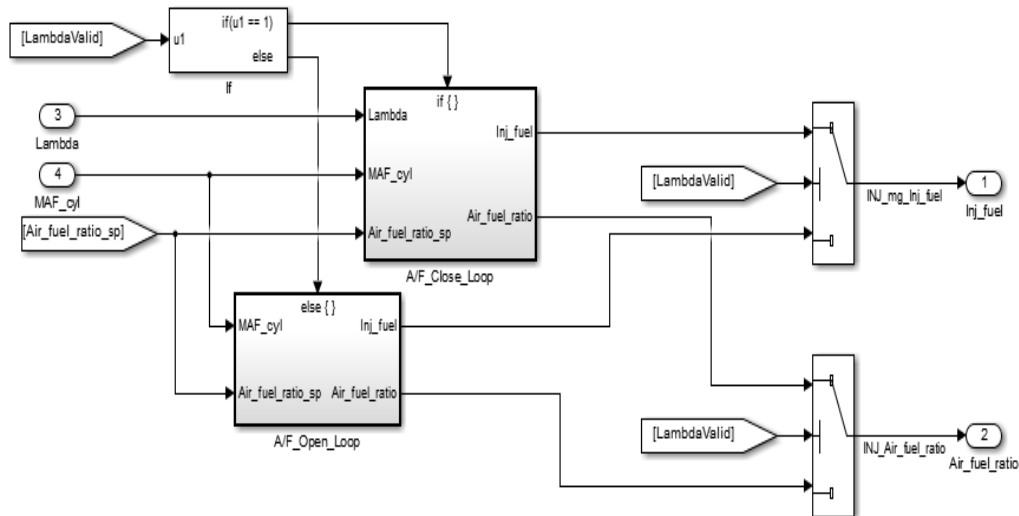


Figure 4 Control strategy of air - fuel ratio

## VI. CONCLUSION

In the engine control strategy, the air-fuel ratio control is essential, the engine running to a certain situation, the exact air mass flow determines the engine fuel supply. For gas engines, accurate fuel supply can make the engine lean, economical and emissions will be better. This paper provides a reliable method to correct the throttle model and obtain a model that can accurately adapt to the air flow of the engine by combining some of the data under the steady state of the engine bench test. Making the engine both in the transient or steady state can get a good response, which is the engine ECU calibration is of great significance.

## REFERENCES

- [1]. Zhang Xizheng. Automotive Engine Electronic Control Technology [M]. Beijing:Mechanical Industry Press,2012,P:78-90.
- [2]. Chen Renzhe.Hardware and Software Development of Gas Engine Electronic Control System [D]. Beijing: Tsinghua University, 2011.
- [3]. Zhou Qinghui. Modern Vehicle Emission Control Technology[M]. Beijing: Peking University Press, 2010.P:56-60.
- [4]. Hendricks,E,Chevalier,A,Jensen.M.,etal.Modelling of the intake Mannifold Filling Dynamics[C],SAE paper 960037,1996.02.
- [5]. Wu Wangyi. Fluid Dynamics[M]. Beijing: Peking University Press, 1983.P:28-40.

\*Huang Mintao. "Study And Calibration on the Intake Flow Control of Multipoint Injection Gas Engine." International Journal of Research in Engineering and Science (IJRES), vol. 05, no. 10, 2017, pp. 65–69.