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A Development of Fuel Efficiency Gauge for Automobiles

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1. INTRODUCTION

Increasing numbers of automobiles have led to more and more negative influence on energy resources and circumstance pollution. People unwillingly suffer so much from a series of mischance such as exceptional disease, unwonted air temperature, earth warm effect and zoology balance destroy. In recent years, in the fields of automobile energy resource technology, are being developed studies and researches on super high combustion ratio, carbon combustion cell, high efficient engine and automobile body lightweight; in the fields of circumstance pollution, are being developed a series of studies and researches on super high combustion ratio, green energy resources, high efficient exhaust and gas decontamination, all of which are used to solve problems of energy resources and circumstance pollution. The reason why people do not purchase automobiles with low fuel economy is that they consume more fuel. In recent years, when choosing automobiles, more and more people pay more attention not only to their size, comfort, safety and acceleration, but also to fuel efficiency and exhaust emission. Especially, taking fuel efficiency into account is no longer a negative action, but an active one. Lack of fuel and increase of price force people pay more attention to high efficient fuel decreasing fuel cost, without blindly pursuing big size, excess comfort, strong power and super safe automobiles. With the progress of engine manufacture technology and electronics technology, have elapsed the times that sacrifice size, safety, comfort or acceleration to increase of fuel efficiency and fuel economy. Simply put, technological improvements have led to increases in fuel efficiency with fewer sacrifices in terms of size, safety, power or speed.

2. SYSTEM DESCRIPTION

This development used speed signal from speed sensor and fuel injection signal from ECU, after micro-processor calculates and processes, results were displayed on LEDs, showing instantaneous distance per unit fuel, so as to instruct drivers to drive automobiles in an economical way, the final aim of which was to economize energy resources, decrease fuel consumption, and amend circumstance. Went without saying, this development can actively contribute much to the decrease of fuel and circumstance pollution. This development was fulfilled with a method different from those ever used before: speed signal and fuel injection signal are acquired directly from speed sensor and ECU respectively, therefore it can ensure accurate information and decrease of development cost. FEG is an universal device which can find an application in any electronic fuel-injection automobiles. The acquirement of speed signal and fuel injection signal is shown in Figure 1. FEG was used on the experiment object Ford's Taurus automobile, the technical specifications of which: maximum mph is 181km/h, 100km distance consumed fuel at an even speed is 12.5 liter, the engine is a 6-cylinder V-type 4-stroke petrolic engine, maximum power is 104 kilowatt, and electrical system voltage is 12 volt.

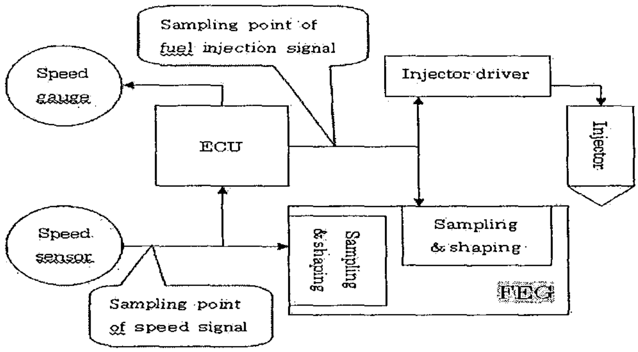

Figure 1. Acquirement of Speed & Injection Signals

2-1. INSTANTANEOUS SPEED - V(km/h)

Figure 2-1 shows that the speed signal obtained from speed sensor, and the converted and shaped pulse signal. While timer/counter count the numbers of pulses in a unit time, the width of each pulse is measured. In a unit time, the numbers of pulses correspond to a definite speed. Assuming that V(km/h) is instantaneous speed, T_i is the width of i_{th} pulse, T_s is the sum of all pulses width in a sampling cycle $T_{speed\ sample}$(= 1 second) gives

$$T_s = T_1 + T_2 + \ldots + T_n = \sum_{i=1}^{n} T_i \qquad (2\text{-}1\text{-}1)$$

where $T_i = T_{i+1}$ or $T_i \neq T_{i+1}$, hence V(km/h) is a function of T_s that is, $V = V(T_s)$

$V(T_s)$ is a non-linear function which is correlated with speed sensor characteristic. Speed sensor sends to ECU a series of pulses or signals which can be converted to pulses. In an unit period, the number of pulses is corresponding to a definite speed, since the width of each pulse is not always the same, so it is the width sum of n pulses in one unit time which is actually corresponding to speed, that is T_s. Assuming that T_0 is the baseline width, T_0 is corresponding to speed V_0, $V_0 \propto T_0$ gives the following mathematics equations:

$$V(T_S) \propto \frac{T_S}{T_O} \times V_O \qquad (2\text{-}1\text{-}2)$$

and

$$V(T_S) \propto \frac{V_O}{T_O} \times T_S \qquad (2\text{-}1\text{-}3)$$

From 2-1-3, assuming

$$V(T_S) \propto \frac{V_O}{T_O} \times T_S + \Delta T_S \qquad (2\text{-}1\text{-}4)$$

and $K_S = \frac{V_O}{T_O}$ gives,

$$V(T_S) = K_S T_S + \Delta T_S \quad (2\text{-}1\text{-}5)$$

where ΔT_s is a non-linear compensation, experiments have shown that ΔT_s is perfectly fitting with a power function: $\Delta T_s = LT_s^2$ A final mathematic equation is obtained:

$$V(T_S) = K_S T_S + Ls\,T_S^2 \quad (2\text{-}1\text{-}6)$$

where K_s and L_s are characteristic parameters correlated with speed sensor and design of ECU; the formula accurately reflects the actual speed characteristic. If necessary, another non-linear compensation $M_s T_s^3$ is introduced:

$$V(T_s) = K_s T_s + L_s T_s^2 + M_s T_s^3 \quad (2\text{-}1\text{-}7)$$

where M_s is just the same as K_s and L_s

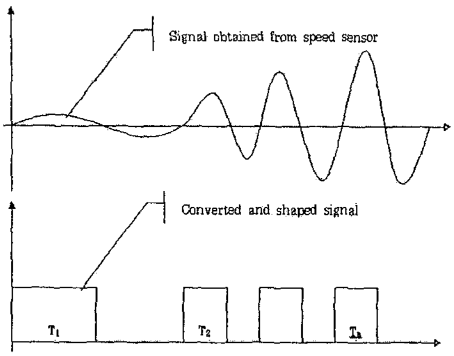

Figure 2-1. Shaped and Un-shaped Speed Signal

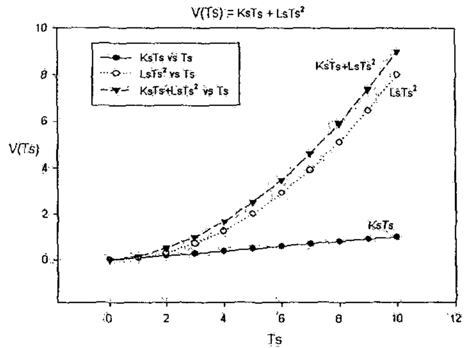

Figure 2-2. Characteristic of Fitted Speed Signal Function $V(T_s)$

2-2. INSTANTANEOUS FUEL - F(ℓ/h)

Figure 3-1 shows the signal sent to injector from ECU and the pulse signal converted and shaped by converting and shaping circuit, and acquired by timer/counter. Timer/counter counts the sum of all pulses within an unit time, and measures the width of each pulse also. Assuming amount of injected fuel is F(ℓ/h), T_i is the width of i_{th} pulse, T_f is the width sum of all pulses within a sampling cycle $T_{fuel\ sample}$ (=1 second) gives

$$T_f = T_1 + T_2 + \ldots + T_n = \sum_{i=1}^{n} T_i \quad (2\text{-}2\text{-}1)$$

where $T_i = T_{i+1}$ or $T_i \neq T_{i+1}$, F(ℓ/h) is a function of injection pulse T_f, $F = F(T_f)$.

The distance that the fuel injector valve lifts or opens is constant. The amount of fuel delivered to the cylinder depends upon how long the fuel injector is actually held or energized electrically. The injector is controlled by pulse-width signal, meaning that the longer the pulse width, then the longer the fuel injector will remain open. Simply put, this means that more fuel will be delivered, and greater speed and horsepower will be the result. The amount of injected fuel is only correlated to the injector open time, T_f $F(T_f)$ is a non-linear function correlated to the injector characteristics. The signals sent to injector from ECU can be converted to a series of pulses and sent to FEG, within an unit time, the sum of pulses is corresponding to a definite amount of injected fuel, not every pulse always has the same width, therefore more accurately speaking, within an unit time, the width sum of n pulses is corresponding to a definite amount of injected fuel, that is, T_f is corresponding to the amount of injected fuel F(ℓ /h).

Similarly assuming that T_0 is the width of a fiducial pulse, the amount of corresponding injected fuel of T_0 is F_0 : $F_0 \propto T_0$ gives the following mathematic equations:

$$F(T_f) \propto \frac{T_f}{T_O} F_O \tag{2-2-2}$$

and $$F(T_f) \propto \frac{F_O}{T_O} T_f \tag{2-2-3}$$

From Eqs.2-2-3, assuming,

$$F(T_f) = \frac{F_O}{T_O} T_f + \Delta T_f \tag{2-2-4}$$

and $K_f = \dfrac{F_O}{T_O}$ gives,

$$F(T_f) = K_f T_f + \Delta T_f \tag{2-2-5}$$

where ΔT_f is a non-linear compensation, experiments show that ΔT_f is perfectly fitting with a power function: $\Delta T_f = L_f T_f^2$, a final mathematics equation is obtained:

$$F(T_f) = K_f T_f + L_f T_f^2 \tag{2-2-6}$$

where K_f and L_f are characteristic parameters correlated with automobile engine injectors and design of ECU the formula accurately reflects the actual injector characteristic. If necessary, another non-linear compensation $M_f T_f^3$ is introduced:

$$F(T_f) = K_f T_f + L_f T_f^2 + M_f T_f^3 \tag{2-2-7}$$

where M_f is just the same as K_f and L_f.

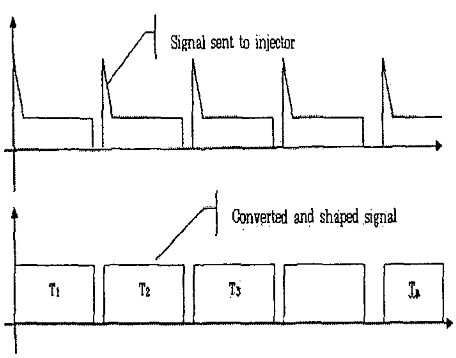

Figure 3-1. Shaped and Un-shaped Injection Signal

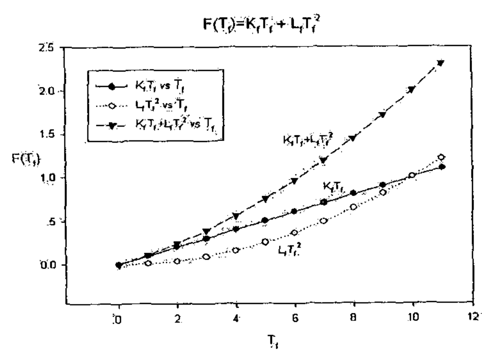

Figure 3-2. Characteristic of Fitted Injection Signal Function $F(T_f)$

2-3. INSTANTANEOUS FUEL EFFICIENCY - FE(km/ℓ)

Assuming that FE(km/λ)is instantaneous distance per liter of consumed fuel,

$$FE(\text{km}/\ell) = \frac{V(\text{km}/\ell)}{F(\ell/h)} \qquad (2\text{-}3\text{-}1)$$

where,

$$V(T_s) = K_S T_S + L_S T_S^2 \qquad (2\text{-}1\text{-}6)$$

and

$$F(T_f) = K_f T_f + L_f T_f^2 \qquad (2\text{-}2\text{-}6)$$

2-4. OTHER FUNCTION

Accumulative consumed fuel(ℓ) is the amount of accumulative consumed fuel after automobiles startup, which is the sum of accumulative consumed fuel(milliliter) within each second, $\sum F(\text{m}\ell/s)$. Accumulative distance(km) is the sum of accumulative distances after automobiles startup, which is the sum of accumulative distances (meter) within each second, $\sum V(m/s)$. Accumulative fuel efficiency(km/ℓ) is the sum of accumulative distances (km) when accumulative consumed fuel is 1 liter. Accumulative consumed fuel per 100km(ℓ/100km) is the amount of accumulative consumed fuel(ℓ) when accumulative distances is 100 kilometers. Instantaneous consumed fuel per 100km (ℓ/100km) = 100 x (the reciprocal of instantaneous fuel efficiency) = 100/FE(km/ℓ)=100×F(ℓ/h)/ V(km/h)

2-5. SYSTEM INTEGRATION FRAME

FEG is made up of CPU, ROM, RAM, transform & shaping circuit, power supply circuit, reset circuit, watching dog circuit, display interface circuit, and display circuit. Figure 4 is the integration frame of the FEG system. CPU is the core of FEG which obtains pulse signals from transform & shaping circuits, calculates and processes them and then sends the results to display circuit. Transform & shaping circuits acquire speed and injection signals, and transform them into pulse signals, and then send results to CPU.

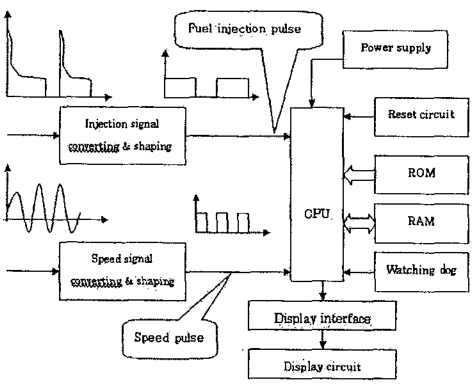

Figure 4. Integration Frame of FEG

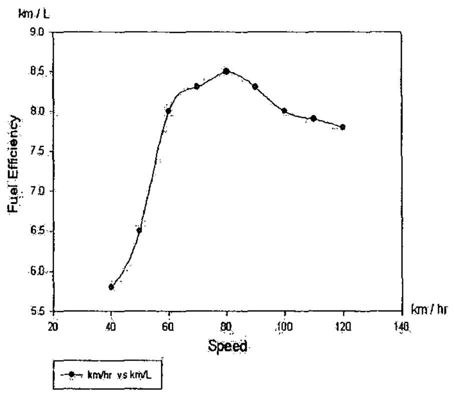

Figure 5. Characteristic of Fuel Efficiency vs Speed

3. CONCLUSION

When FEG was developed, serious and careful considerations were how to simply implementation of functions and decrease cost. Speed signal and fuel injection signal were acquired directly from speed sensor and ECU respectively. Based on many experiments, functions of signals were obtained, which is the core of our development, and also the foundation simplifying implement and decreasing cost of the system. FEG was tested on Taurus, after many experiments, some useful information was gained: the amount of consumed fuel is high and serious when urgent accelerating, urgent starting off, and urgent starting up; the amount of consumed fuel is about 20% higher when speed is 100 to 120㎞/h than that when speed is 70 to 80 ㎞/h; the engine efficiency is highest when speed is about 80 km/h(shown in Figure 5.); extra 10% to 20% of consumed fuel is needed when air-conditioner is switched on. From the information mentioned above, the FEG has a better accuracy. Although nowadays, less drivers pay attentions to the instantaneous efficiency of fuel when driving, as serious lack of fuel resources and rapid increase of fuel prices emerge, more and more people will pay more attentions to fuel economy. Therefore, the development of FEG will actively contribute much to the decrease of energy resources and circumstance pollutions.

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