Fuel Consumption Saving Strategy and Realization of Honda Eco-car Engine

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Abstract: In the race of Honda Eco Mileage Challenge (HEMC), with the engine from the organizing committee, the Binhai Team makes different kinds of methods and strategy to reduce fuel consumption of eco-car. In this study, the engine 1-D simulation model is built in software GT-Power and 3-D model is made in UG. With GT-Power the engine intake and exhaust system and compression ratio are optimized and analyzed. In order to realize light weight, several parts of the engine are cut off. Besides, electrical control system is calibrated. Lubrication and starting system are adjusted to adapt to the race.

1. Introduction
Honda Eco Mileage Challenge (HEMC) is sponsored by Mr. Koichiro who is the founder of Honda. It was founded from 1981. There are more than 500 teams all over the world every year. In China, it starts from 2007 and has been hosted 13 times from then on. From the regulation [1], the HELC is a competition even to challenge the energy-saving extreme with racing car made by the teams independently. In which the engine is supplied from Honda company and can be modified according the regulation at will, which is 125CC, 4 strokes, single cylinder, air-cooled. The competition result ranks based on the fuel consumption by running 4 cycles at the velocity of above 25km/h.

There are kinds of ways of energy-saving on the engine.

Li et al. [2] discussed the main technologies of powertrain products, such as GDI, turbo, start-stop, vvt, downsizing, the new diesel common rail, engine control system, diesel engine post-processing, multiposition AT, hybrid Electric.

Pei et al. [3] proposed an innovative hierarchical topological graph approach, which includes four design processes. With a dynamic program, it can estimate the fuel economy and the acceleration performance.

2. 1-D Engine model and analysis
In HELC, Honda company provides the engine. The parameters of engine are shown as Table 1. The engine simulation model includes intake system, exhaust system, cylinder, engine block et al. According to the physical size of engine, the 1-D model is built in software GT-Power shown as Fig.1.
| Item                        | Content                  |
|-----------------------------|--------------------------|
| Strokes                     | four                     |
| Cooling                     | Air-cooled               |
| Displacement (mL)           | 125                      |
| Cylinder                    | 1                        |
| Compression ratio           | 9                        |
| Combustion form             | SI                       |
| Rated power (kW/rpm)        | 6.2/7500                 |
| Maximum torque (N·m/rpm)    | 9.7/5000                 |

2.1. Compression ratio (CR) improvement

CR is one of the most important parameters and can affect the performance greatly. It means the ratio of cylinder total volume to combustion chamber volume. The formula can be shown as following.

\[
\varepsilon = \frac{V_a}{V_c} = \frac{V_h + V_c}{V_c} = \frac{V_h}{V_c} + 1
\]

(2)

Where \( \varepsilon \) is the CR; \( V_a \) is cylinder total volume (CTV); \( V_c \) is combustion chamber volume (CCV); \( V_h \) is working volume (WV).

From the formula, it can be derived that CR is proportional to the WV, and inversely proportional to the CCV. If you want to increase the CR, you can reduce the CCV or raise WV. CCV depends on the shape of piston top and CTV. CCV can be increased by modifying the piston top. So by thickening piston top can increase the CR. According to engine model from Fig. 2, the torque and power change of the engine can be obtained at the speed of 4500 rpm and full load as Fig. 2. It shows that as CR rises, torque and power of engine and cylinder peak pressure also increase. Fuel in the cylinder can be evaporated faster and more easily. Fuel particles become much thinner. The mixture will be much easier ignited and combusted more rapidly. Combustion becomes completely, and the power output becomes much higher. But when CR is more than 12, there is light piston knock in the cylinder. When CR increases, the pressure and temperature also increase. Local overheat points in the cylinder turn to flame kernel and self-ignite irregularly. The irregular flame knocks against the regular flame from spark plug. Then knock occurs. Besides, if CR is too high, the compression block making and installation will be too hard. Considering the analyses above, 12 is the most suitable for CR. From the formula (2), CCV is 10.43ml. Based on the piston top and combustion chamber shape, the compression block is designed as Fig. 3-(a). The piston will be processed to Fig. 3-(b). The assembly drawing is Fig. 3-(c). The material is selected as the 6067 aluminum alloy. The processed block is assembled onto the piston top with bolt and connected with thermal stable adhesive. Then put the piston into high temperature circulating cabinet and keep for time circulating as Fig 4.
2.2. Optimization of intake and exhaust system

The intake manifold pipe length is modified from 20mm to 50mm. The power and cylinder peak pressure change as Fig.5. Generally, power and peak pressure decrease as the pipe length decreases from 34 to 50 and also increase from 20 to 34. Considering the space of installation onto engine, 34mm is the most suitable length of engine. The reason is that the shorter the pipe, the smaller air inlet resistance. It can increase the inlet volumetric efficiency, then increases the power.
Exhaust pipe length is changed from 300mm to 600mm. It is shown from Fig.6 that power and cylinder pressure increase as speed rises. At most of the speed, the pressure of different length changes greatly. However, the pressure and power of 600mm length is much higher than others at almost each speed. Besides, considering the installation, there should be no interference. Relatively 600mm is the most suitable length.

3. Other measures of reducing fuel consumption

3.1. Dual-spark plug technology
The original engine uses single spark plug. Under low load and speed condition, the flame propagates slowly. At the most conditions, the car runs below 55km/h. The engine speed is lower than 4000rpm. The throttle valve is often in rapid acceleration condition. In order to improve the ignition energy and power performance, dual-spark plug structure is designed and made. From the 3D graph Fig.7, the original spark plug is nearby the two valves. The second spark plug is designed at the symmetric position.
3.2. Lightweight of engine
In order to decrease weight of the car, engine cutting is absolutely necessary. From the Fig.8, the engine cutting involves to transmission, cylinder head, engine block and so on. The principle of cutting is less influence on the engine performance and running. Transmission is not used on the car, so it’s cut off first. Then oil pump is taken down. By lubrication field test, it’s shown that the engine lubrication is not reduced since adding oil at the begging of race. Besides, there are some other parts of cylinder head and engine block cut off. The total weight cut off of engine reduces by 30%.

3.3. Electronic control calibration
Electronic control calibration can in the maximal degree exploit potential of engine performance [4,5]. Change the original electronic control system into a new one. The data in new ECU can be calibrated with software Procal [6]. According to the race rules and running conditions, the team calibrates the engine alone and match the car on the racetrack. The conditions include cold start, rapid acceleration, idle, uniform motion. The projects calibrated include injection pulse width and ignition advance angle. The aim is to increase power and reduce the fuel consumption.

3.4. Lubrication and battery
Lubrication in the engine is very important and essential. So in order to ensure enough oil on friction pair in the engine, oil charge must be reasonable – between the upper and lower scale. However, in this race the team member disassembly the oil motor, and block oil ports to avoid oil leakage. Before the race start, just add oil enough. During the practice in our playground, several field tests show that the oil is enough to complete the race. There is almost little effect on the friction pair.

If the electric quantity of battery is loss too much, the engine start will fail. Or the engine would not start successfully once time. Maybe the engine starts twice or three times or even more times. The racing car will stop on the racetrack or the fuel consumption will rise. In order to ensure that engine starts once time successfully, the battery electric quantity must be charged fully. Besides, the battery should be minimization to ensure engine lightweight.

4. Conclusions
There are kinds of energy saving ways on the engine. A great many works and researches have been done on it. In this study, based on the racing engine from HEMC organizing committee, energy saving
strategy and methods are researched from the aspects of optimization and application. It can be summarized as follows:

(1) Increasing compression ratio and optimization of intake and exhaust pipe length can improve the power of engine obviously. Then fuel economy could be realized indirectly.

(2) Dual-spark plug technology application can also increase the ignition energy, which will increase the power output.

(3) Cutting off the engine reduces weight by 30%.

(4) Electronic control calibration and lubrication are helpful to fuel economy.

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