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Performance Optimization of CNG Bi-fuel Vehicle for Reaching 100 g/km of CO_2 Emission

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Abstract

Recently CO_2 reduction targets are a big challenge for the mobility sector because about 20% of all CO_2 emissions origin from road traffic. For this reason, the demand for clean, renewable and affordable alternative energy is forcing the automotive industry to look beyond the conventional fossil fuels. Natural gas represents today a promising alternative to conventional fuels for vehicles propulsion, because it is gaining interest due to the worldwide ratio of assured reserves of natural gas and crude oil shifting towards natural gas. Above all, CNG is an environmentally clean alternative to the existing spark ignition engines with the advantages of minimum change. The main motivations for the use of natural gas focused by the European community are oil substitution, source diversification and independency of fuel supply as well as the reduction of greenhouse gases especially CO_2. The European commission defined a target share of 10% natural gas vehicles in the European community by 2020. In this study was installed bi-fuel system that a conventional 1.4 liters gasoline engine was modified to run on natural gas by a gas injection system. Experiments were mainly carried on the optimization of an ECU control strategy affecting the emission characteristics of CNG/Gasoline bi-fuel vehicle. The test results was reached 100g/km of CO_2 emission for the CNG bi-fuel vehicle, it was also reduced 17% compared to gasoline fuel on the NEDC mode. Also the amount of CO and HC emissions in bi-fuel and gasoline modes were found to equality.

Keywords*:* CNG, Bi-Fuel vehicle, ECU, NEDC, CO_2.

1. Introduction

Natural gas as an alternative fuel for petroleum has both fuel economy and low emissions with rich reserves and cleanliness, particularly excellent stability, very good combustion characteristics with high octane number and a wide combustion margin. Therefore, it has been considered excellent fuel in terms of carbon dioxides (CO2) emission[1-2)]. However, in the case of domestic, until now natural gas vehicles have been mainly consisted of city bus and recycling truck because of difficulties such as infrastructure and insufficient technology development in related components, and research and development have been concentrated on the bi-fuel or dual fuel due to lack of compressed natural gas (CNG) filling stations.

On the other hand, generally the engine for bi-fuel is difficult to apply to the low emissions vehicles required precise control such as start-up, air-fuel ratio, acceleration and deceleration due to the different fuel characteristics and combustion characteristics start-up, the air-fuel ratio, and exhaust emissions remain at the level of EURO 4 ~ 5.

In this study, CNG fuel system was developed by using 1.4 liter gasoline car with the least modification of engine for applying the CNG vehicles whose research and development focused on mainly heavy duty vehicles to the passenger cars.

In addition, through the electronic control unit (ECU) control strategies and optimization for ultra-low-emission CNG engine meets the EURO 6 which is the regulation of European ultra-low-emission vehicles. Moreover, CO2 emissions were achieved 100 g/km, which resulted 16% reduction of CO2 compared to the equivalent petrol car.

2. Experimental apparatus and method

2.1 Engine control of the CNG / Gasoline bi-fuel vehicle

In general, bi-fuel vehicles have been widely used due to difficulties of the CNG vehicle such as infrastructure. However, there are difficulties due to the different fuel properties in applying to the ultra-low-emission vehicles with the precise control such as start-up, air-fuel ratio, acceleration and deceleration.

In this study, both bi-fuel system and mono-fuel system were constructed and each ECU system for engine control of CNG vehicle was developed to understand the emission characteristics of CNG vehicle.

Fig.1 is a schematic diagram of the CNG / gasoline bi-fuel engine system with different fuel properties and combustion characteristics. Control logic of the ECU for the bi-fuel was converted to be optimized for CNG by detecting the injection timing of gasoline ECU. The control logic is the system for driving the CNG injector based on the injection driving signal of gasoline ECU system.

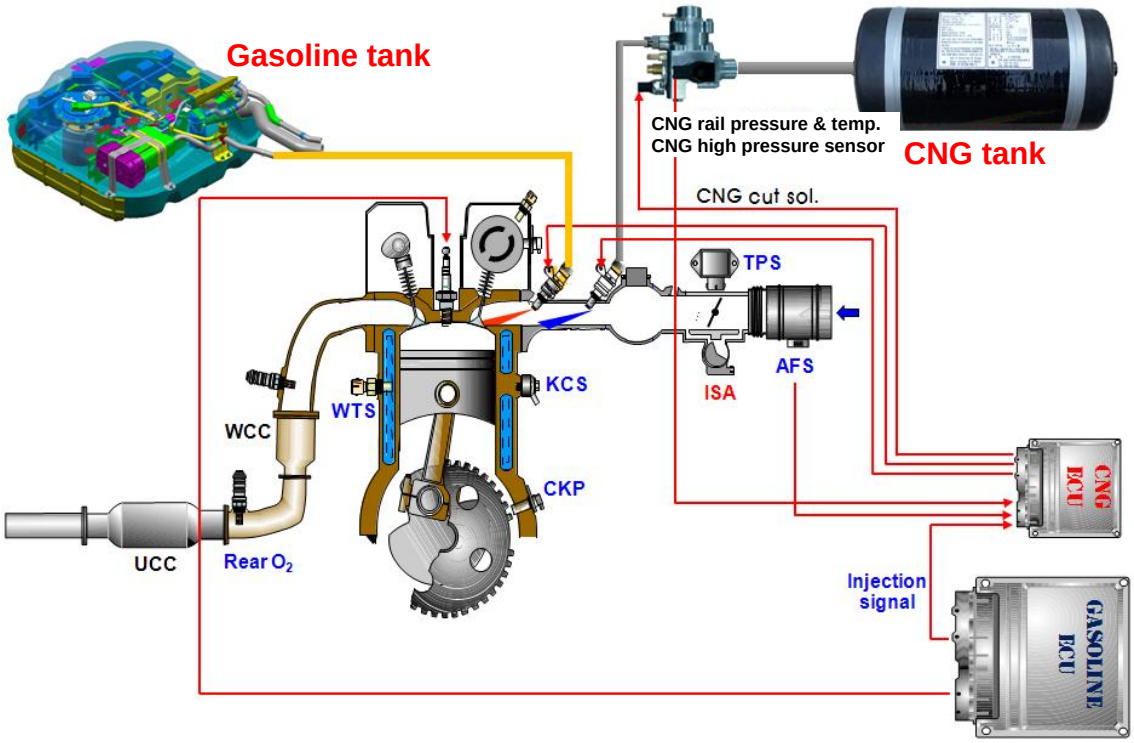

Fig. 1 Schematic diagram of CNG/Gasoline bi-fuel system

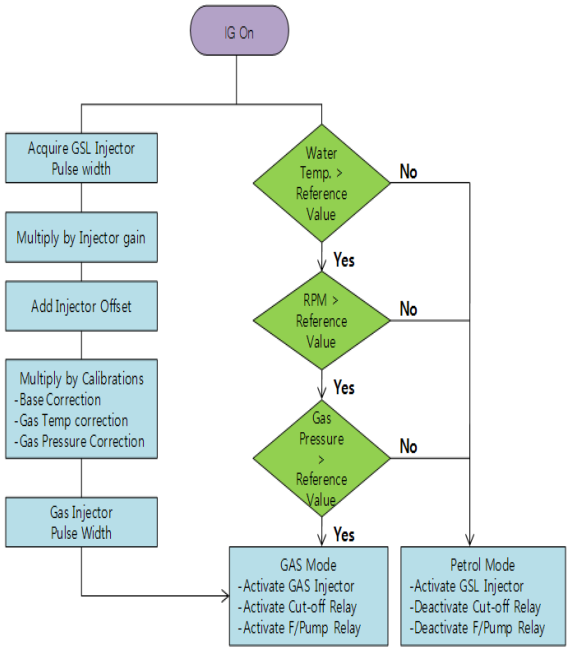

Fig. 2 Flow chart of testing procedure.

CNG injectors to be driven when the operating conditions of the CNG injector are satisfied by the means of gas temperature and pressure, rpm of the vehicle, cooling water temperature and otherwise, the gasoline injector will be driven.

In this study, strategy was utilized as gasoline for start-up and CNG for warm stabilization on the basis of cooling water temperature at 40°C.

Fig.2 shows the flow chart of testing procedure.

2.2 Vehicle emissions testing

In order to optimize the emission characteristics of CNG vehicles, the 1.4 liter gasoline engine was optimized by adding the fuel system of CNG with the minimum modifications of engine. The CNG rail pressure was limited at 7 bar. Table 1 shows the brief specifications of the vehicle used in this experiment. Fig.3 is the photo of test vehicle.

Table. 1 Specification of test vehicle

Test Vehicle	Accent
Model year	2011
Displacement	1,396 cc
Fuel	CNG/Gasoline
T/M	MT' 5 speed
Odometer	10,000 km
Tire	175/70R 14

Fig. 3 Photo of test vehicle

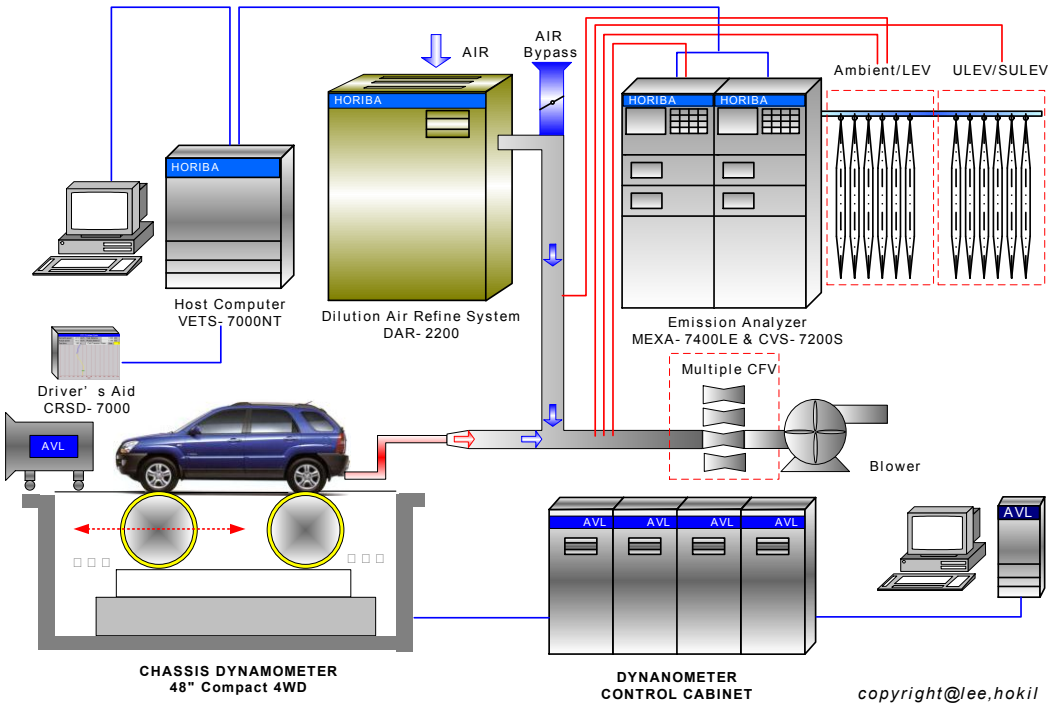

Fig. 4 Schematic diagram of vehicle emission test

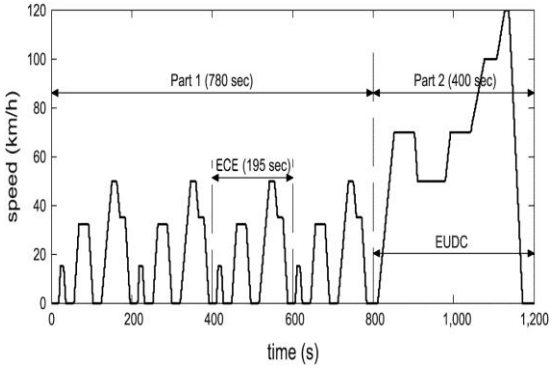

Fig. 5 NEDC mode driving pattern

Fig. 4 is a schematic diagram for the exhaust gas test of vehicle, the chassis dynamometer which was an AVL 48-inch single-roll type was used to simulate the road load condition of the vehicle and the exhaust gas measurement was conducted using MEXA-7200 of HORIBA for measuring the total amount of exhaust gas concentrations in real time during the experiment.

NEDC mode as a test mode of vehicle for measuring the fuel economy and exhaust gas of current European passenger car and small cargo vehicle is composed of city driving mode of ECE-15 in Part 1 and high-speed driving mode of EUDC (Extra Urban Driving Cycle) in Part 2 as shown in Fig. 5. Total running time was 1,180 seconds, the average speeds of the vehicle in Part 1 and Part 2 were 18.7km/h and 62.6km /h, respectively [3].

3. Results and discussion

In this study, CNG fuel system was developed by using 1.4 liter gasoline car with the least modification of engine for applying the CNG vehicles whose research and development focused on mainly heavy duty vehicles to the passenger cars.

As shown in Fig.6, although total hydrocarbon (THC) emissions were increased, CH4 component removed non-methane hydrocarbon (NMHC) emissions were comparable. It was caused from CH4 which is the main component of CNG fuel (THC accounted for over 42% of emissions).

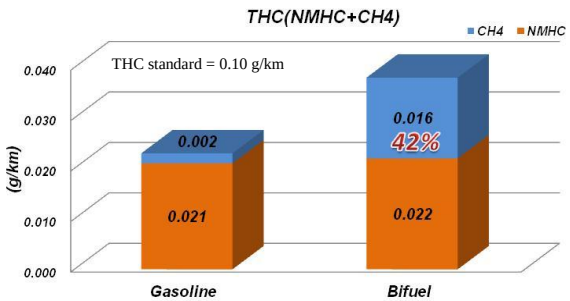

Fig. 6 Comparison between CH4 and NMHC emissions

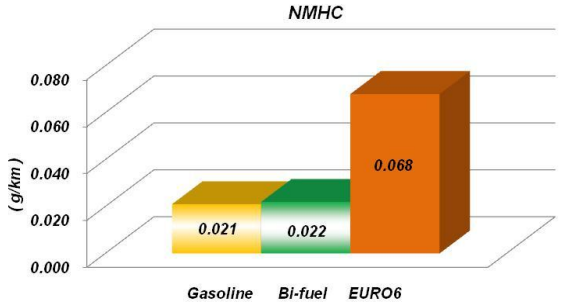

Fig. 7 NMHC emissions along with gasoline, bi-fuel and Euro-6.

A large amount of exhaust gas produced due to the switching operation during the initial CNG fuel from poor injection control. CNG injectors caused poor control from cold start operation.

In Fig.8, CO emission was the lowest in bi-fuel compared with gasoline and Euro-6 regulations.

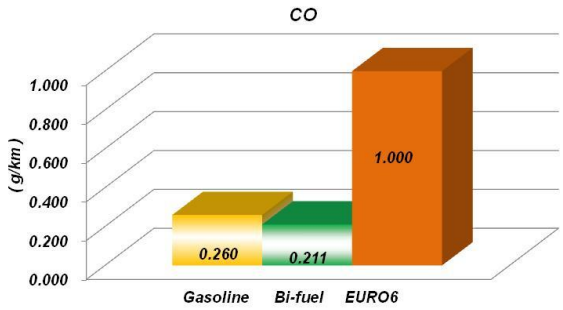

Fig. 8 CO emission along with gasoline, bi-fuel and Euro-6.

In Fig.9, NOx emission was generated the minimum amount when bi-fuel is used as a fuel. It was caused from the low combustion temperature.

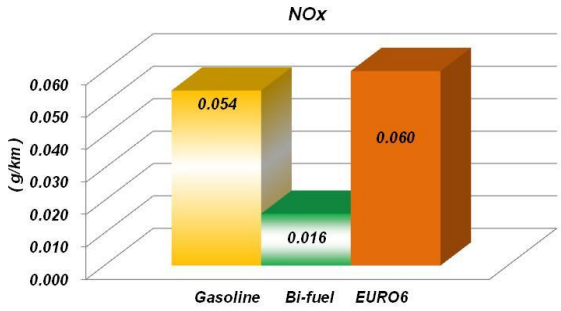

Fig. 9 NOx emission along with gasoline, bi-fuel and Euro-6.

As can be seen from the Fig.10, CO2 emissions are 107g / km, which is reduced by an amount equal to at least 25% compared to gasoline vehicles.

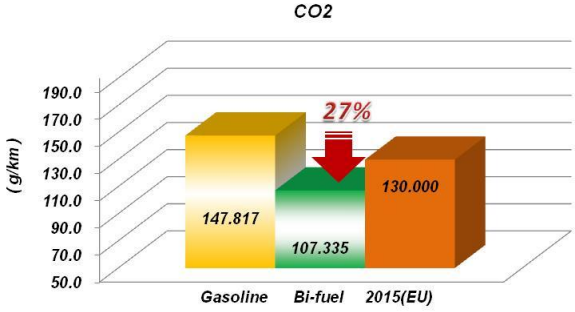

Fig. 10 CO_2 emission along with gasoline, bi-fuel and Euro-6.

Fig.11 shows the CO_2 emissions as a function of time in the NEDC mode. Bi-fuel resulted the lower CO_2 emission during the NEDC mode.

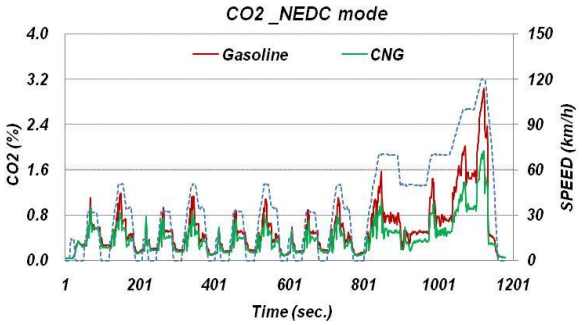

Fig. 11 CO_2 emission on the NEDC mode along with gasoline, bi-fuel and Euro-6.

4. Conclusion

In this study, in order to apply the CNG car that has been developed mainly for large vehicle to spread the meantime, passenger cars and 1.4 liter petrol car after using the least amount of engine modifications, CNG / gasoline Bi fuel the fuel system was built, and the performance of the ECU through a control strategy for the second low-emission and optimization Bi-fuel engines can be obtained the following conclusions.

If the vehicle CNG Bi-fuel compared to gasoline vehicles converted before THC component CH4 emissions are increasing, but the level of emissions is equivalent to removing NMHC, CH4 major component of the CNG fuel accounts for about 42% of the THC emissions

In the case of CNG Bi-fuel vehicles, refurbished prior gasoline vehicles could be obtained approximately 25% or more of CO2 reduction compared to fuel economy by the carbon balance method it was achieved the 16.63km/m^3 level.

Through optimization of the exhaust characteristics of the CNG Bi-fuel cars in Europe were ultra-low emission vehicle exhaust meets the regulations of EURO 6 emission standards, CO2 emissions are noted achieve the 107g / km level.

5. Acknowledgement

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