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Study on Performance and Exhaust Gas Characteristics When Biogas is Used for CNG Converted Gasoline Passenger Vehicle

Sul-Ki Choi

Graduate School of Automotive Engineering
Kookmin University, Seoul 136-702, Korea

Doo-Sung Baik

Computer-aided Mechanical Design Engineering
Daejin University, Pocheon 487-711, Korea
(Corresponding Author)

S. W. Lee

Graduate School of Automotive Engineering
Kookmin University, Seoul 136-702, Korea

Abstract

Because the of limitations of conventional fossil fuel reserves and worse environmental pollution including global warming effect, alternative energy will continue to be in demand. In Korea, CNG vehicles have been increased specially in metropolitan city buses. However, passenger vehicles fuelled with CNG have not been produced due to the infrastructure of gas stations. And CNG gas stations for CNG fuel are available at only bus garages. Many conventional passenger gasoline vehicles have been converted for the CNG fuel supply because the CNG fuel is cheaper than gasoline fuel. Meanwhile, biogas is much cheaper than CNG fuel but it has many different gas mixtures and heat release rate and

engine power are relatively lower than CNG fuel. This study aims to provide problems in converting to CNG vehicle by understanding vehicle performance and emission characteristics when biogas fuel is applied to a CNG converted gasoline passenger vehicle.

Keywords: CNG (Compressed Natural Gas), Bio-gas, NOx, CO_2, CO, HC

1. Introduction

Many passenger gasoline vehicles have been converted for CNG fuel and for last 2 years about 5,000 gasoline vehicles have been converted for CNG fuel and inspections have been completed for service in Korea [1-4]. Around the first half of 2011 year city gas act was amended so that biogas could be mixed and transported through the existing domestic or commercial city gas pipes. In addition biogas manufacturing procedure has been developed in different ways [5-6]. For example, biogas occurring from the treatment process of the sewage treatment plant located at Kangseo-gu Makok-dong in Seoul has been supplied to converted CNG passenger vehicles for service frequently. Biogas is an attractive source of energy for rural areas and it can be produced from the process of anaerobic digestion of many other many other natural sources such as animal waste and also from plant matter. Since it composed of approximately two-thirds methane (CH_4) by volume, carbon dioxide, hydrogen and nitrogen, it is able to give enhanced performance and reduced emissions under appropriate operating conditions [9]. Meanwhile spark-ignition engine operation with biogas containing inert gases such as CO_2 and N_2 demonstrates problems in engine performance compared with natural gas or gasoline [7-10]. Biogas has extremely lower energy density, heat releasing rates, flame velocity compared with natural gas. It also contains a small percentage of H_2S which can cause corrosion problems. Water scrubbing has been introduced as an effective method of eliminating CO_2 and H_2S in biogas [11-12]. Yet biogas is attractive as an eco-friendly renewable energy resource and the biogas price is 30~40% cheaper than CNG fuel. This research aims to investigate the performance and emission characteristics of supplied biogas fuel under an optimal CNG mapping or biogas mapping and compare emissions from conventional gasoline or CNG fuels and provides measures for problems when biogas fuel is used a substitute for CNG or gasoline fuel.

2. Experimental Setup and Procedure

The experiment was conducted on a chassis dynamometer and the experimental conditions were represented in Table 1. The room temperature was maintained constantly. Gasoline, CNG and biogas were used and fuel setting was made by AC-Gas program. For the purpose of safety, bombe for CNG fuel was replaced by nitrogen. CVS-75 mode was used in order to figure out an engine problem and characteristics of fuels. First of all, basic setting for CNG was made after CNG fuel was fuelled in bombe. And then after idle and driving was made for 30 minutes and an optimized mapping for CNG fuel was completed. And the test was conducted in CVS-75 mode three times. Similar process was taken for biogas fuel. The test was made by supplying biogas instead of CNG fuel while basic CNG setting was made. The third test was done for biogas fuel with basic biogas setting.

Table 1 Experimental conditions

Test vehicle	Lincon Towncar 4.6 V8
Fuels	Gasoline, CNG , Biogas
Emission	NOx, CO, CO_2, THC, CH_4
Test Mode	CVS-75 (HOT P1~P2)

Figure 1 represents a chassis dynamometer. The emission measuring test on the chassis dynamometer was conducted by Horiba. The test vehicle was Lincon town car SOHC V8 4600cc vehicle and naturally aspirated type. The gasoline vehicle was modified to use CNG and biogas fuel. A gas bombe of Type3 composite 106 liter used and Motonic 2 stage pressure regulator used. Valtek 3 Ohm made in Italy was used for an injector and AC Syntro made in Portland was used for ECU control. The input data for calibration were controlled by injection timing from a gasoline injector, engine loads and oxygen rates form an oxygen sensor. Furthermore, the calibration had to be precisely made to adjust amount of CNG fuel or bio-gas fuel so that injected CNG or bio-gas fuel might be closely same as the injected gasoline fuel when gasoline fuel was changed to CNG or biogas fuel. Calibration for ECU control in vehicle test was conducted by following procedures. First of all, engine information such as ignition coil type, fuel type, number of cylinder, rpm signal, engine load, coolant temperature, transitional timing, injector specifications for fuel types and regulator specifications were provided as input data.

Figure 1 Chassis Dynamometer and Charging Bombe

The operating pressures for a regulator were set to 2, 4, 6 and 8 bar. This procedure was repeated until an ECU value for gasoline fuel could be read. When a temperature for engine coolant reaches higher than 50 degree, ECU calibration was ready to start. First, injection data and loads for gasoline fuel were read and stored for 30 seconds in the beginning. And, next step was set by changing gasoline fuel to bio-gas fuel in accordance with firing order 1-5-4-8-6-3-7-2. Through the AC program calibration for bio-gas fuel was completed successfully when injection timing and engine MAP (Manifold Air Pressure and oxygen sensor waveform was within tolerance compared with those of gasoline fuel.

3. Results and Discussions

Experiments were conducted on a chassis dynamometer as shown in Figure1 and THC, CO, CO_2, CH_4 and NO_x were measured for the four different cases of applied fuels such as gasoline, CNG, biogas in CNG mapping and biogas in biogas mapping.

In gasoline fuel THC emission emitted the least among four fuel cases and THC in CNG fuel emitted the second least and biogas fuel at optimal CNG mapping was the third one and biogas fuel at optimal biogas mapping was the last one (Figure 2). This is because the test vehicle was optimized for the gasoline fuel but not for the CNG or biogas fuel. In addition, this is because the applied catalyst performance was optimized to gasoline fuel.

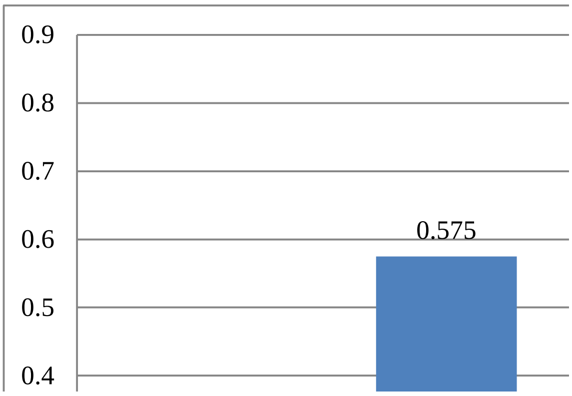

Figure 2 THC Emission

CO emission from gasoline fuel emitted much more and the second one was from CNG fuel (Figure 3). The third one is from biogas at an optimal CNG mapping. And CO emitted the least from biogas at an optimal biogas mapping. CO emitted more when air/fuel mixture is richer in general. Since gasoline in liquid phase is richer than CNG or biogas fuels in gas phase physically, CO emission from gasoline exhausted more than from CNG or biogas.

CO_2 emissions were similar from four different fuels and CO_2 emission emitted more from gasoline fuel than others (Figure 4). This is because CNG or biogas fuel has lower carbon contents than gasoline while it consists of more isooctane C_8H_{18}.

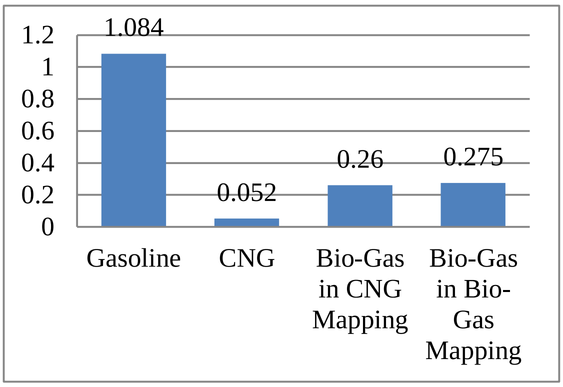

Figure 3 CO Emission

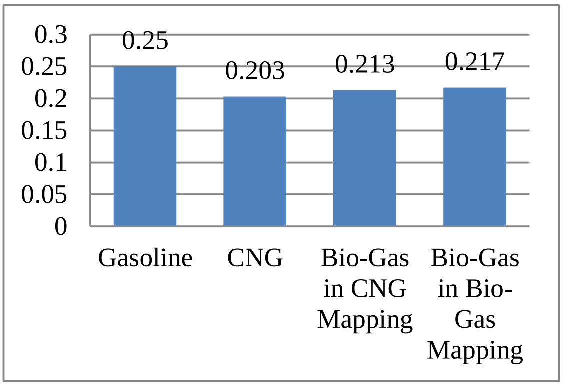

Figure 4 CO_2 Emission

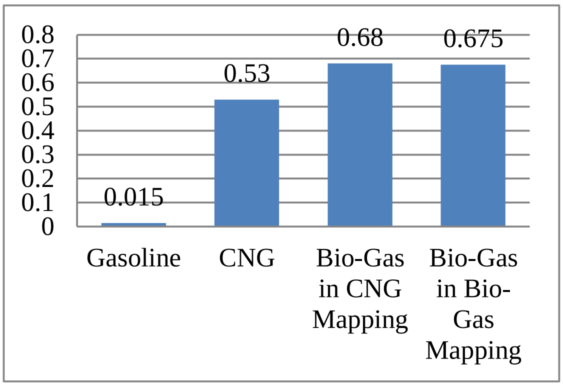

Figure 5 CH_4 Emission

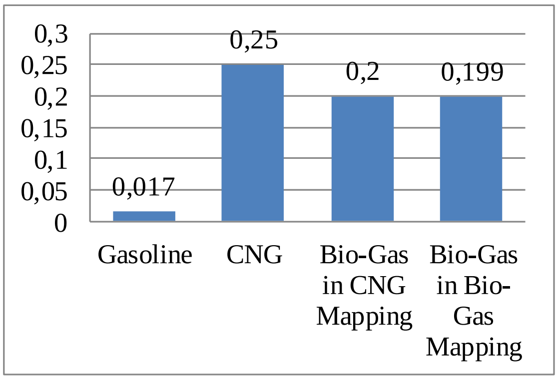

Figure 6 NO_x Emission

In addition, CO_2 emission exhausted more when combustion condition becomes favorable by sufficient air supply.

CH_4 emission emitted the least from gasoline fuel and the second least one was from CNG fuel (Figure 5). CH_4 emitted more from biogas fuel at both mapping cases of CNG and biogas. This is because CNG fuel originally contains 87~88% methane and biogas contains 97~98% methane. NO_x emission from gasoline fuel exhausts the least compared to other cases. NO_x emissions are similar both from biogas at an optimal CNG mapping or an optimal biogas mapping (Figure 6).

4. Conclusions

Gasoline vehicle was converted for CNG fuel and charged with CNG and biogas fuels. After optimal mappings were conducted for gasoline, CNG and biogas, emission tests for NO_x, CO, CO_2, THC and CH_4 were made and following conclusions were made.

1. In gasoline fuel THC emission emitted the least among four fuel cases and THC in CNG fuel emitted the second least and biogas fuel at an optimal CNG mapping was third one and biogas fuel at an optimal biogas mapping was the last one.
2. CO emission from gasoline fuel emitted much more and the second one is from CNG fuel. The third one is from biogas at optimal CNG mapping. And CO emitted the least from biogas at an optimal biogas mapping.
3. CO_2 emissions are similar from four different fuels and CO_2 emission emitted more from gasoline fuel than others.
4. NO_x emissions are similar both from biogas at optimal CNG mapping or biogas mapping.

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