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A Study on Experiment of CNG as a Clean Fuel for Automobiles in Korea

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Abstract

Gasoline engines have proven their utility in light, medium and heavy duty vehicles. Concern about long term availability of petroleum and the environment norms by the increased vehicular emission have mandated the search for safe fuel. CNG is an environmentally clean alternative to the existing spark ignition engines with the advantages of minimum change. A higher octane number and a higher self ignition temperature make it an attractive gaseous fuel. The thermal efficiency is better than gasoline for the same engine. The reduced carbon mono oxide, carbon di-oxide, hydrocarbon emissions is a favorable outcome along with a slight increase in NO_x emission when compared with gasoline fuel to a dual fuel mode in the existing spark ignition engines. The result from the experiment shows that CNG could be a potential substitute fuel that maintains performance and emissions characteristics in gasoline engines.

Key words : Clean fuel, Exhaust emissions, Natural gas vehicles etc.

1. INTRODUCTION

Energy is considered as an index of economic growth and social development. Oil makes up the greatest share of Korean total energy consumption, about 50%, coal contributes 24% followed by nuclear power (14%) and natural gas (12%). Hydropower and other renewable energy sources make up a small fraction of the total energy consumption (EIA, Energy Statistics, US). Distribution of primary energy in Korea based on world statistics in 2008 is shown in Table 1 (BP Statistical Review of World Energy, 2008).

Use of renewable and bio origin fuels can significantly meet energy requirement and restrict atmospheric CO_2. Vehicle emissions standard and environmental factors, stress for gas emission reduction. Various of heavy-duty vehicles and engines (Graham *et al.*, 2008; Han *et al.*, 2000) have been tested with a range of different fuels including diesel, biodiesel, compressed natural gas, hythane (20% hydrogen, 80% CNG), and liquefied natural gas, with different after treatment technologies were studied. Distance based emission rates of CO_2, CH_4, and N_2O were reported with fuel consumption calculated by carbon balance from measured emissions. The measurement result shows that for heavy-duty diesel vehicles without after treatment, that while CO_2 emissions dominate, CH_4 emissions account for between 0% and 0.11% and N_2O emissions account for between 0.16% and 0.27% of the CO_2 equivalent green house gas emissions. Linoa *et al.* (2008) studied the feasibility of the electronic control injection pressure in a

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Table 1. Distribution of primary energy in South Korea and world (million ton of oil equivalent).

	Oil	Natural gas	Coal	Nuclear energy	Hydro electric	Total
Korea	107.6	33.3	59.7	32.3	1.1	234.4
World	3952.8	2637.7	3177.5	622.0	709.2	11099.3

new common rail injection system for CNG engine to prove that performances and pollutant emissions reduction can benefit from a precise control of the injection pressure. Present study was done on a gasoline engine, converted to run in a dual fuel mode operation. Gasoline and CNG were used at different engine speed for different fuel operating conditions to evaluate the performance and emissions characteristics.

2. PROPERTIES OF GASOLINE AND CNG FUEL

Natural gas refers to combustible gas with methane (CH_4) as the main element. CNG has many advantages that enable an engine to operate with little knocking at high compression ratio. In addition, gasoline and diesel engines are easily converted into CNG engines without major structural changes (John, 1992). CNG engines give high thermal efficiency and power. It advantage when striving for lean combustion resulting in low fuel consumption and less NO_x production (Kim *et al.*, 2008; Kim *et al.*, 1999). CNG engine also yields very low levels of particulate matter emissions when compared with other conventional engines. These facts found in experimental study performed to explore combustion and emissions characteristics of both gasoline and CNG fuels using a converted spark ignition engine (Aslam *et al.*, 2006). The number of CNG vehicles is increasing and older vehicles are being converted into CNG vehicles through engine modifications (Ryu and Kim, 2006). The major components of CNG kits for a petrol vehicle are: pressure regulator, petrol solenoid valve with manual changeover switch, on-off valve and refueling connector, control module/change-over switch, CNG level indicator, gas air mixer, CNG cylinder, low-pressure gas hose, ignition advance processor, high pressure gas tube, wire harness. CNG cylinders are designed to maximum pressure of 200 kg/cm^2 (about 2,840 pounds per square inch (gauge).

Table 2. Fuel properties.

Properties	Petrol	LPG	CNG
Chemical composition	C4 to C10	C3 to C4	CH_4
Specific density at 15°C (kg/litre)	0.73	0.54	0.14
Boiling point at 1 bar (°C)	25 to 110	−50 to 0	−162
Lower heating value (MJ/kg)	43.5	46.1	47.7
Ignition temperature in air (°C)	220	400	540
Lower ignition limit (vol % gas)	0.6	1.5	5
Upper ignition limit (vol % gas)	8	15	15
Stoichiometric air/fuel ration (kg/kg gas)	14.8	15.5	17.2
Fuel octane rating RON	95	105	120
Fuel octane at 25°C (bar)	82	97	120

Important fuel properties are shown in Table 2. CNG has a specific gravity of 0.587 and is lighter than air; any CNG leak will rise up into the atmosphere and dissipate. CNG has a self-ignition temperature of 700°C as compare to 455°C for petrol. CNG form a fuel air ratio of 4% to 14% by volume for combustion to occur that represents a narrow range than petrol. Lubricating oils are extended because CNG does not contaminate crankcase oil. The absence of lead content eliminates the lead fouling of sparkplugs which increases sparkplug life. Exhaust emissions consist of water vapor and a small fraction of carbon mono-oxide; the exhaust fumes are negligible with a good distribution mixture quality. Research octane number of CNG is 130 as compared to 87 for premium motor gasoline. Modification in CNG system involves higher compression ratio used to take advantage of higher octane number and valve timing for exhaust valves opens late in the power stroke.

3. EXPERIMENTAL PROCEDURE

Hyundai makes Elantra gasoline engine (a four cylinder, air and coolant radiant system; fitted with an electronic controlled unit (ECU) direct injection) which is primarily used for light automotive vehicles was selected for the experimental work. Specification of the engine is shown in Table 3. It is essential to find various instruments mounted at the appropriate location on the experimental setup to conduct the set of experiments to obtain data. Fuel flow diagram of the system is shown in Fig. 1.

For the dedication of the CNG engine some parameters need to modify. To take the advantage of higher octane number higher compression ratio could be abtain for valve timing, the exhaust valve needs to open lately in power (combustion) stroke. As CNG requires high energy for ignition: therefore strong spark plug is necessary for the ignition system. Also the ignition timing needs to be advanced. Some other modifications/change are necessary in valve seat head gasket etc. After converting the automobile to CNG fuel.

Table 3. Specifications of the gasoline engine.

Type	Elantra 1.5 DOHC engine
Displacement	1,497 cc
Maximum output	106 ps/6,000 rpm
Maximum torque	14.6 kg m/4,500 rpm
Bore	79.7 mm
Piston area	4,989 mm^2
Stroke	75 mm
Cylinder volume	374,175 mm^3
Piston speed	15 m/sec
Tolerance weight	1,166 kg

4. RESULTS AND DISCUSSION

4.1 Performance characteristics

Performance characteristic of the test engine on gasoline and CNG was evaluated. Graph obtained under operating conditions shown in Fig. 2. It gives the complete view of the output signal obtained during the running of the engine. Change in the map sensor reading indicates manifold pressure changes that vary less than gasoline engine characteristics. Initially, vacuum pressure is high and drops when the engine is boosted. This shows the relationship of spark timing and fuel mixture. Power output decreases as compared to gasoline due to lower flame velocity and is in a gaseous state that produces less volumetric efficiency. The lower fuel consumption with natural gas is due to a higher heating value. Thermal efficiency is higher due to greater heating value and better mix. Improved efficiency is due to better mix that tends to become homogeneous.

4.2 Exhaust temperature

Fig. 3 shows the variation of exhaust gas temperature with the rpm for gasoline and CNG fuel. The results in all cases show that the exhaust gas temperature increased with a coinciding increase in rpm. Highest value of exhaust gas temperature of 103°C with the CNG and 100°C with gasoline was observed at full. This is due to the difference in combustion

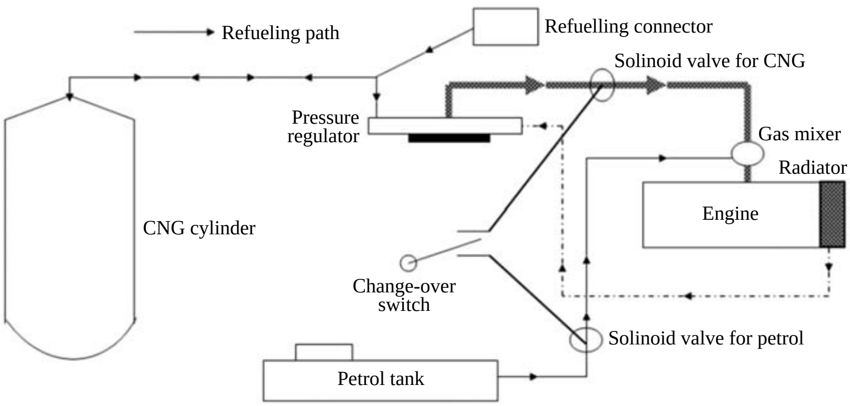

Fig. 1. Schematic diagram of the experimental set up.

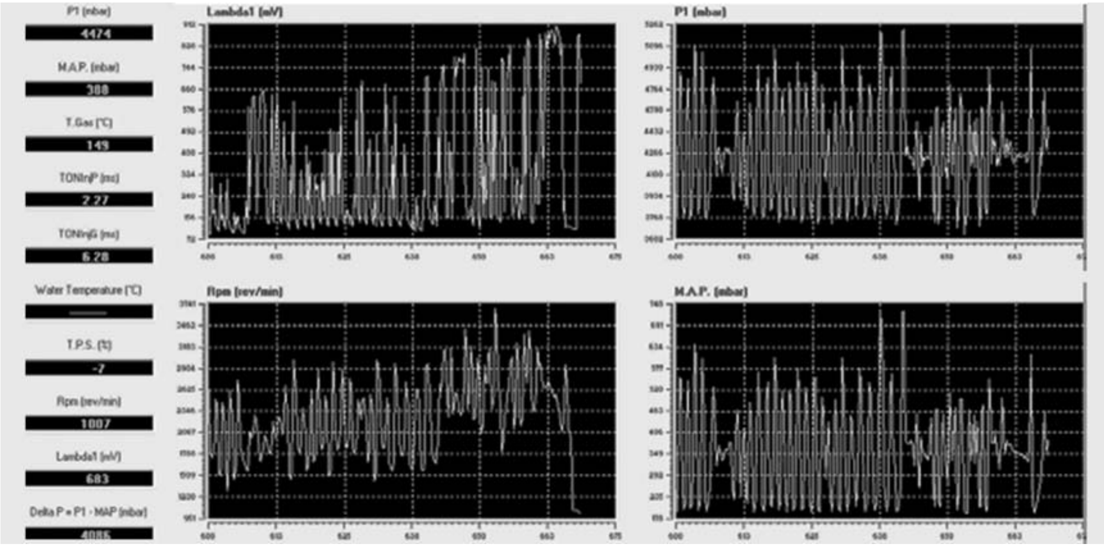

Fig. 2. CNG with working rpm.

characteristics of the CNG and gasoline because of the retarded spark timing, idle mixture adjustment, faster idle speed, and lean mixture operation for exhaust temperature.

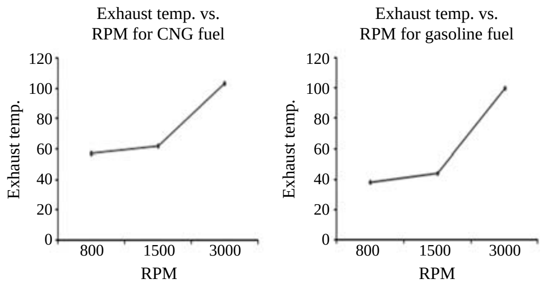

Fig. 3. Exhaust temperature at different rpm.

4.3 NO_x emissions

Fig. 4 shows that within the range NO_x emissions from the petrol are lower than that of CNG fuel. NO_x emissions increase with increase in engine rpm due to a higher combustion temperature in the engine cylinder and the local air-fuel ratio of the mixture. In engines where combustion takes place under high pressure in the reaction zone of the flame is very thin. As the pressure rises during the combustion and flame propagation the temperature of the burnt gases are more than those reached immediately after combustion. The highest NO_x emission is 86.5 ppm for gasoline. In spark ignition engines due to lean air-fuel ratio and lower flame temperatures of natural gas lower levels of NO_x emissions are encountered. This emission characteristic of NO_x for CNG is a useful tool for the application of CNG to diesel engines as a type of fuel for petroleum-based ordinary fuel.

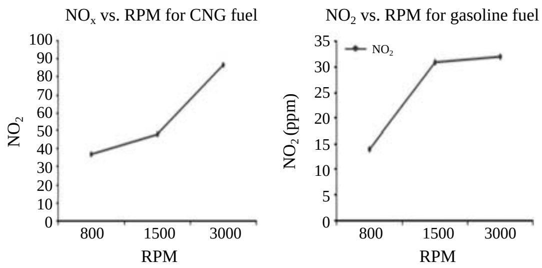

Fig. 4. NO_x emissions at different rpm.

4.4 CO emissions

Fig. 5 shows the comparison of the CO emissions at

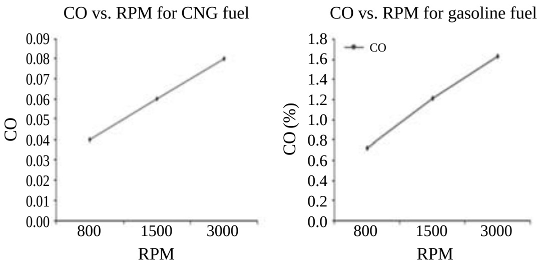

Fig. 5. CO emissions at different rpm.

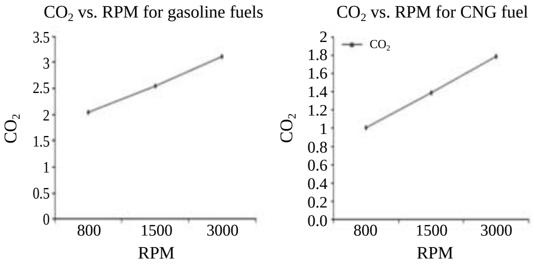

Fig. 6. CO_2 emission at different rpm.

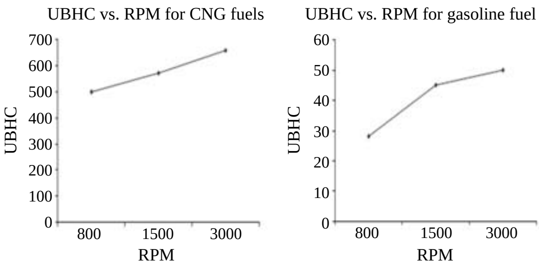

Fig. 7. UBHC emission at different rpm.

different engine rpm. The CO emissions from petrol are higher than that from CNG. To reduce CO emissions, the efficient atomization of fuel ensures the proper air mix, reduction of richness during deceleration and idling during rpm variations. CO emission is the result of incomplete combustion indicate the function of overall mixture strength, the efficiency with which the fuel air is mixed and the length of time available for combustion. CO emissions with CNG are lower because it forms a homogenous mixture with air that runs leaner than gasoline engines. CO is low during a cold start since CNG engines do not require cold enrichment additives.

4.5 CO_2 emissions

The variations of CO_2 emissions are shown in Fig. 6 at different rpm. CO_2 emission of CNG is lower than that of the other gasoline fuels. This is because of the amount of fuel evaporation going into the intake manifold (under hot shut down conditions) is high and the mixture formed is too rich to ignite resulting in high CO_2 emissions that contain oxygen elements. The carbon content is relatively lower in the same volume of fuel consumed at the same engine rpm, consequently the CO_2 emissions from the CNG are lower, but the combustion inside the cylinder optimizes with an increase in temperature.

4.6 Un-burnt hydro carbon emissions

The results of variation of un-burnt hydrocarbon (UBHC) emissions for petrol and CNG are shown in Fig. 7. The HC emissions of all the fuels are lower at idling or at lower loads, but increased at a higher rpm or loading. This is due to the less oxygen relatively available for the reaction when more fuel is injected into the engine cylinder at a higher engine load. Flame extinction in the bulk gas in certain operating conditions is one of the major sources of HC emissions. As cylinder pressure falls during the expiration stroke the temperature of the unburned mixture ahead of the flame decreases and the temperature falls too rapidly, this may extinguish the flame. This phenomenon normally occurs during idling and light load conditions or if the mixture is too lean.

5. CONCLUSIONS

The objective of the present investigation was to evaluate the suitability of CNG as a fuel for spark ignition engines and to evaluate the performance and emissions characteristic of the engine. Experimental result shows that performance with CNG fuel is inferior to gasoline and if the CNG fuel mixture is homogeneous the engine performance can be improved. The use of natural gas as a vehicle fuel allows a high compression ratio with good lean combustion characteristics, clean burning attributes, less CO_2 per unit of energy than gasoline. The use of natural gas vehicles, in light commercial vehicles, passenger cars and mainly in heavy-duty vehicles that replace diesel in Korea is advantageous in pollution reduction with little tendency for emissions that efforts can be made for a potential reduction in NO_x emissions. The results from the experiments suggest that CNG is a potential clean fuel for diesel engine or gasoline engines.

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