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# 한국의 잠재적인 연료인 CNG연료의 성능 및 배출물에 관한 연구

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# The Study on Performance and Emission of CNG as a Potential Fuel in Korea

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요 약

가솔린 엔진은 전 세계적으로 중소형 및 대형차 등 전반적으로 사용되고 있으며, 장기적으로 차량 부하에 따른 배기가스의 증가가 주변 환경에 대한 위협이 가중되고 있어 여기에 대한 대처가 필요하다. CNG엔진은 기존의 가솔린 SI 엔진에 비하여 유해 배출가스 농도가 적어 다른 연료에 비해여 청정연료로서 유리하며, 많은 관련 연구자들이 여기에 대한 여러 논문을 통하여 잠재적 청정연료로서 확인되었다. 출력과 열효율의 측면에서 약간 가솔린 연료에 비하여 떨어지지만 일산화탄소와 탄화수소 배출량은 유리하며, 질소산화물은 약간 증가하는 현상이 나타났다. 본 논문에서는 기존 가솔린엔진과 CNG엔진의 배출물을 비교 검토하였다.

**Abstract** - Gasoline engine have proved its utility in light, medium and heavy duty vehicle in every sector of the world community. The concern about long term availability of petroleum and the increasing threat for the environment by the increasing load of vehicular emission, compel the technology to upgrade itself for meeting the challenges. CNG is environmentally clean alternative to the existing SI Engines with out much change in the hardware. Many researchers have found this as a potential substitute to meet the energy requirement. Higher octane number and higher self ignition temperature make it a good gaseous fuel. Although power output is slightly lesser than the gasoline it's thermal efficiency is better than the gasoline for the same SI Engine. Results showed that reduced CO, hydrocarbon emissions is a favorable outcome, with slight increase in NOx emission when compared with gasoline fuel to dual fuel mode in the existing SI Engines.

Key words : octane number, self ignition temperature, emissions, thermal efficiency,

## 1. Introduction

Concern over high levels of pollutants in vehicular exhaust gas, and associated government regulations specifying limits on them, has led to much research into methods of reducing such emissions.

Environment protection and energy conservation have become increasingly important worldwide issues these years, especially in the auto industry where researchers keep looking for effective ways to control vehicle emissions for decades. Alternative fuels representing fuels that have great potentials and are not massively used today is thought to be a promising approach. Natural gas (NG) is a good alternative to traditional vehicle fuels due to its cleaner combustion characteristics and plentiful resources. Engines fuelled

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by NG emitted less carbon monoxide and reactive hydrocarbons (non-methane HC) compared to a gasoline engine, but the emissions of nitrogen oxides may be still not low enough to meet the increasingly stringent emission regulations[1]. CNG, which is regarded as one of the most promising alternative fuels due to environmental benefits (high H/C ratio and high research octane number), and economical and geo-political reasons, considering that its sources are bigger than those of oil. Nevertheless, besides existing concerns regarding the distribution network, several technical problems related to bi-fuel engines still need to be investigated, particularly to determine the optimal set point for the best compromise between emissions and fuel economy and to exploit the CNG potentialities to run the engine with very lean mixture and high compression ratios, keeping low NOx and HC emissions[2]. Recently, to reduce pollutants (CO, NOx, and HC) and particulate in the atmosphere, manufacturers have experimented engines employing alternative fuels ascompressed natural gas. CNG can keep the emission limits within international prescriptions of EURO 4 and can also restrain the operation costs. Energy conservation and management has since become the buzz word in industrial circles and ‘energy’is considered as a major component in the production cost. With limited domestic energy resources, South Korea is almost entirely dependent on imports to meet its energy consumption needs. South Korea is the fifth-largest net importer of oil in the world, and second importer of liquefied natural gas (LNG). Oil makes up the greatest share of South Korea’s total energy consumption, though its share has been declining gradually in recent years[3]. In an summit of energy, while recognizing varied national circumstances among the 11 participating countries, given the fact that we collectively account for about 65% of the global energy consumption, we must play an important role in achieving global energy security, climate change mitigation and sustainable development[4].

Table 1. Distribution of primary energy in south korea and world (MTOE) : (Source: BPSR 2008).

| | Oil | Natural Gas | Coal | Nuclear Energy | Hydro Electric | Total |
|---|---|---|---|---|---|---|
| South 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 |

## 2. DESIRABLE PROPERTIES of IC ENGINE FUELS

CNG has emerged as an attractive alternative automobile fuel due to its clean burning characteristics and very low amount of exhaust emissions. Petrol driven vehicles can use CNG by installing a Bi-Fuel Conversion kitand the converted vehicle has the flexibility of operating either on CNG or petrol. Diesel Engines can also be converted to run on CNG by installing a dual fuel kit or converting the existing diesel engine into a Spark Ignition one. Moreover as compared to Petrol, CNG has a higher Octane Number of 120 and higher Self Ignition Temperature of about 540 degree C. The important properties desired from a fuel are as -high energy density, good combustion qualities, high thermal stability, low deposit forming tendencies, compatibility with engine hardware, good fire safety, low toxicity, low pollution, easy transferability, easy onboard vehicle storage. Natural gas is predominantly methane. Exact composition depends on whether it is associated gas or non-associated gas. Associated may content significant amount of heavier hydrocarbons such as ethane, propane, butane together with lighter liquids such as pentane hexane to opt for CNG as a potential substitute we consider following points summarized as that it should mix readily with air and afford uniform manifold distribution i.e. it should easily vaporize. It must be knock resistant. It should not pre-ignite easily. It should not tend to decrease the volumetric efficiency of engine. It should be easy to handle. It must be cheap and should be available everywhere. It must burn clean and produce no corrosion, etc. on engine parts. It must have a high calorific value. It should not form gum and varnish. All these requirements are connected in one way or other to the properties like volatility, knock-resistivity, sulphur content, gum content, contamination etc.

## 3. Thermodynamic Properties of Gasoline and Alternative Fuel

Table 2, following data shows comparable fuel properties between gasoline petrol and compressed natural

Table 2. Comparable fuel properties:[5].

| Properties / Fuels | Gasoline | $CH_4$ |
|---|---|---|
| Boiling Point, deg C @1bar | 30-225 | (-)160 |
| LHV (mass) MJ/kg fuel | 44.5 | 50 |
| Octane Number (Research) | 90-98 | 120 |
| Stoich. A/F ratio, mass | 15.04 | 17.2 |
| Flammability limit in air vol.% | 1.4-7.6 | 5.3-15 |
| Adiabatic FlameTemp. K (at stoich. Ratio) | 2266 | 2227 |
| Auto iginition temp.,K | 743 | 853 |
| Molecular weight | 110 | 18.7 |

Table 3. Typical pipeline quality of natural gas:[5].

| Constitute | Source-I | Source-II | Source-III |
|---|---|---|---|
| Methane | 84.50 | 88.42 | 82.55 |
| Ethane | 7.70 | 8.79 | 7.67 |
| Propane | 2.40 | 1.59 | 3.85 |
| I-Butane | 0.26 | 0.29 | 0.64 |
| N-Butane | 0.32 | 0.28 | 0.78 |
| I-Pentane | o.18 | 0.05 | 0.13 |
| N-Pentane | 0.19 | 0.05 | 0.14 |
| Hexane | 0.17 | 0.04 | 0.09 |
| Nitrogen | 0.12 | 0.20 | 0.07 |
| CO2 | 4.23 | 0.27 | 0.07 |

gas as methane[5].

Table 3. following data shows comparable fuel characteristics of source-Ⅰ, source-Ⅱ and source-Ⅲ[5].

The general block diagram of the dual fuel arrangement is as shown in fig.-1. The essential components in dual fuel operation as-One or more storage cylinder, Gas regulator (Three stage), Gas air mixer, Fuel selector switch, Solenoid valves, Fuel gauge, Master shut off valve.

## 4. Modifications required in dedicated CNG engine

The MBT timing should take into account the reduction of flame speed and the increase of combustion duration under lean conditions. Usually, MBT spark

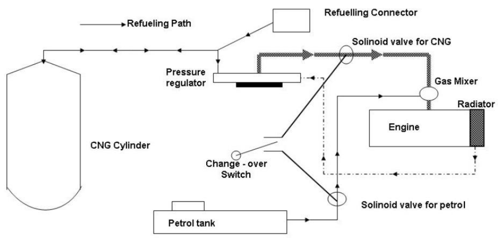


Fig. 1. The general block diagram.

advance varies with the composition of natral gas and air-fuel ratio for low fuel consumption and emission. If ignition timing were overly retarded in a lean burn engine, the mixture temperature in the end zone could drop below the misfire temperature due to expansion and quenching. Compare to SI gasoline engines, engine out NOx emissions for stoichiometric natural gas engines with early spark timing are lower due to lower combustionvelocity while engine out THC emissions stay low at full loads.s

## 5. Performance and emissions from CNG engines

The study was carried out for a variable compression ratio Ricardo engine. It is a single cylinder, naturally aspirated, four stroke, vertical, air-cooled engine. through flexible coupling. The engine can be hand started using decompression lever and is provide with centrifugal speed governor. The lubrication system used in this engine is of wet sump type, and oil is deliverse to the crankshaft and the big end by means of a pump mounted on the front cover of the engine and driver form the crankshaft. Specifications are bore 96.52mm, stroke 95.25mm, connecting rod 166.62mm, inner valve seat 41.58mm, maximum valve lift 8.38mm, inlet valve opens 4.5 BTDC, exhaust valve closes 4.8 ATDC and engine speed 900 rpm. Also, exhaust gas analyzer equipment was used MEXA 9100. From the graph given below we can analyze.

1) Thermal efficiency: (refer to fig. 2). 5-10 percent higher thermal efficiency due to greater heating value and better mixing. 3-5% greater thermal efficiency improved with NG is due to better mixing, mixture tend to become more homogeneous.
2) Power output: (refer to fig. 3).10-15 percent lesser power as compared to gasoline due lower flame

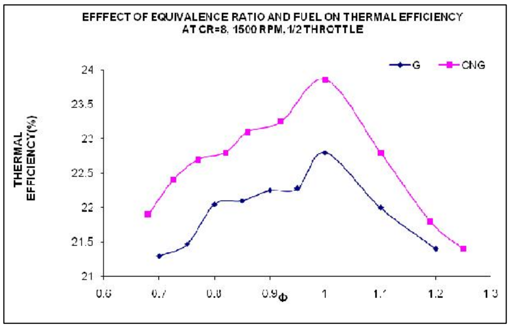


Fig. 2. Thermal efficiency.

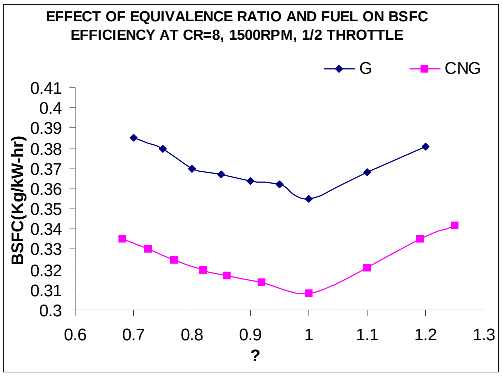


Fig. 3. Break specific fuel consumption.

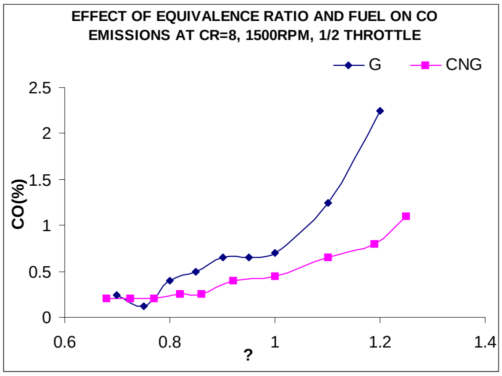


Fig. 4. CO Emissions.

velocity and also being in gaseous state produces less volumetric efficiency. 15% lower Fuel Consumption Lower FC with NG due to higher heating value. (Gasoline-44.5MJ/Kg NGas-50MJ/Kg).

3) CO Emissions: (refer to fig. 4). CO emission is

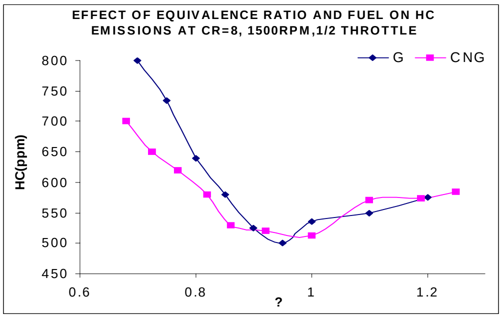


Fig. 5. HC Emissions.

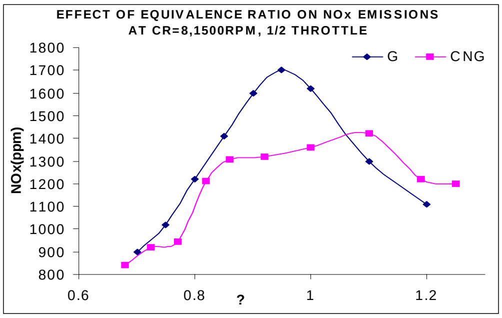


Fig. 6. NOx Emissions.

the result of incomplete combustion and is a function of overall mixture strength, the efficiency with which the fuel and air is mixed and the length of time available for combustion. CO emissions with NG are lower because it easily forms more homogenous mixture with air and can run leaner than gasoline engines. Since NG engines do not require cold enrichment CO is low during cold start. At $\varphi$=1.2 CO emission was 80% lesser than gasoline.

4) Hydrocarbons: (refer to fig. 5). Total hydrocarbon emissions in NG vehicles tend to be higher, since methane is slower to react than other hydrocarbons and in very lean mixtures, the flame speed may be too low for combustion to be completed in the power stroke. However, the non methane hydrocarbons (NMHC) or reactive HC emissions, which are of real concern, are considerably lower. It is estimated than the reactive HC emissions are only 15-20% of the total HC emission from the NGVs.

5) Oxides of nitrogen (NOx) Emissions: (refer to

fig. 6).Therate of formation of NOx is exponentially dependent on temperature. In S.I. engines, due to lean air-fuel ratio and lower flame temperatures of natural gas, lower levels of NOx emissions are encountered. However, in dedicated CNG vehicles, where the ignition timing andcompression ratio are optimized, the NOx levels are expected to be higher.

## 6. Conclusion

The use of natural gas as vehicle fuel with octane number (>120) allows high compression ratio in Otto engines; good lean combustion characteristics, clean burning; abundant, under-utilized resour-

ce with negligible sulfur/toxic content; less CO2/unit of energy than gasoline or diesel. The use of Natural Gas Vehicles (NGV), in light commercial vehicles, passenger cars and mainly in heavy-duty trucks and buses (replacing diesel) in Korea is advantageous greatly to reduce, little tendency for PM emissions to increase with age and poor maintenance; potential reduction in NOx emissions can be done upto30%–60%for lean-burn mixture .

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