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Evaluation of Comparative Analysis in the Use of Petrol and Compressed Natural Gas (CNG) As Vehicular Fuel

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Abstract: *Petrol driven engines are the major contributor of environmental pollution. Environmental problems are well talked and written about but public and private sectors sensitivity remains very high. However, amidst the understanding that petrol driven engines contributes to about 15% green house gases, petrol shows no sign of quitting the energy scene. Therefore, one wonders if petrol engines offer better performance than CNG engines?. This paper is intended to answer this question by not just revealing the limitations delaying the full utilization of CNG but by carefully evaluating recent studies carried out on comparative studies of CNG engines and petrol engines. The evaluation is done based on; Performance, Storage and Safety, Maintenance, Emissions, Economy and Cost, Technology, Refueling, Refueling Station Cost, Engine Conditions, Legislation and Incentives, Adequacy of fuel supply, process efficiency, ease of transport and safety of storage, modifications needed in the distribution/refueling network in the vehicle, fuel compatibility with vehicle engine (power, emissions, ease of use, and durability of engine)and the Market place which is drawn from experimental results and conclusions made from recent studies.*
Keywords: *CNG, Engine, Vehicle, Pollution, Performance, Petrol (gasoline).*

I. Introduction

Petrol are highly volatile fuel which contains hydrogen and carbon in various combinations, it evaporates due to heat effect at higher rate and then produces carbon dioxide (CO2) which pollutes the atmosphere. The pollution has significant effect on the environment and human health.

The un-burnt petrol, carbon monoxide, leaded compounds from leaded petrol and other gases which pollutes the air are deadly and harmful to humans, animals and food crops. Lead poisoning causes retarded mental and physical development, reduced attention spans, increased blood pressures, hypertension, higher risk of cardiovascular disease and premature deaths. The World Health Organization (WHO) estimates 15-18million children in developing countries suffers from permanent brain damage due to lead poisoning.

Apart from the above stipulated effects of petrol on the environment and humans, its effect on engines is not left out. It gives low thermal efficiency, less torque and has greater risk of fire due to the fact that it is highly volatile and combustible. Therefore, looking at all these problems posed by petrol as a vehicular fuel, the search for a more environmentally friendly and cheaper fuel continues.

1.2 Purpose of Study

Petrol driven engines have dominated the energy scene for decades now and their utilization is increasing every day despite the campaign for other alternative fuel and coupled with the fact that they contribute more to green house gases, they show no sign of quitting the energy scene. Therefore, one wonders if petrol offers better performance than CNG? This paper is intended to answer this question by evaluating recent studies carried out on comparative studies of petrol and compressive natural gas (CNG) as vehicular fuel.

1.3 Benefit of Research

The findings will give an insight of which fuel is more appropriate for emerging economies like Nigeria in terms of engine choice and Technology. It will also enable researchers and other private organization to know the limitations delaying the full utilization of compressed natural gas (CNG) as vehicular fuel.

1.4 Previous Work Done

The issue of replacing CNG as an alternative fuel to petrol has been addressed by many researchers to a large extent. And this aspect plays the major role in this research work as it presents recent studies done on the comparative analysis in the use of petrol and CNG as vehicular fuel. The following are the previous work done**:**

According to Semin (2009) the research of applying natural gas as an alternative fuel in engines will be an important activity, because the liquid fossil fuels will be finished and will become scarce and most costly.

CNG has some advantages compared to gasoline and diesel fuel from an environmental perspective. It is a cleaner fuel than either gasoline or diesel fuel as far as emissions are concerned. CNG is considered to be an environmental clean to those fuels. Another that, the advantages of CNG as a fuel are octane number is very good for SI engines. Octane number is a fast flame speed, so the CNG engine can be operated in high compression ratio.

According to Munde Gopal, G (2012), the compressed natural gas vehicles exhibit significant potential for the reduction of gas emissions and particulates. There are many problems for compressed natural gas applications such as onboard storage due to low energy volume ratio, knock at high loads and high emission of methane and carbon monoxide at light loads. However these can be overcome by the proper design, fuel management and exhaust treatment techniques.

Mr. Saravanan V.S, Dr. P.S. Utgikar, Dr. Sachin L Borse (2013) carried out an Experimental Study on Conversion of 4 Stroke Gasoline Internal Combustion Engine into Enriched Compressed Natural Gas Engine To Achieve Lower Emissions and the following remarks were drawn; Reduction in CO, CO2 and HC emissions at 25% throttle opening with CNG as fuel as against Gasoline were 81.81%, 34.96%, 39% respectively while NOx increasing 27.58%. Similar results at 50% of throttle opening were 54.6%, 29.25% and 41.07%, while NOx increase was 76.97%. At 100% of throttle opening similar results showed 76.2%, 28.85% and 77.37% while NOx increase was 82.84%. Under the same engine operations and configurations, sequential port injection CNG operations shows 20% reduction in Mechanical efficiency was observed at 25% throttle.

Air fuel ratio is reduced by 43%, 38.35% and 18% at 25%, 50% and 100% throttle respectively. CNG produces less 8-16% of torque compared to gasoline. Considerable improvement in the emission characteristics of the engine using CNG fuel as against gasoline, at all remaining conditions.

M. K. Hassan, I. Aris, S. Mahmod, R. Sidek (2010) worked on Experimental investigations of performance and exhaust gases, concentration at various ignition and injection timing for high compression engine fuelled with compressed natural gas (CNG) engine. The engine implements central direct injection (ID) method. All injectors are positioned within a certain degrees of spark plug. The results showed that, Low CO concentration occurs at late injection timing and the lowest emission is 0.011% when we applied 300 bTDC of ignition at 3600 CA injection timing. The most influential factor for CO development is ignition timing. Complete combustion occurs at (3000 EOI, 250-280 bTDC) as illustrated in the CO2 and O2 contour.

Mardani Ali Sera et al (2008) had investigate the effects of density on the performance of a CNG fuelled engine either in dual-fuel, bi-fuel or dedicated forms is lower performance compare to that of gasoline. One significant factor that reduces the CNG engine performance is its low volumetric efficiency due to low density of a CNG fuel. In this research the cooling system and heat exchanger device were installed to 16 LEFI engine to vary the density of CNG fuel. The results showed that the fuel density plays an important effect on the performance of CNG engine and at the same time maintaining the lower exhaust emission.

Many researches were studied the performance and exhaust emission of port injection using CNG such as How Heoy, Taib Iskandar, Shahrir Abdulla and another experimental investigation using a 1.5 L, 4-cylinder Proton Magma retrofitted; results shows that CNG has the low brake mean effective pressure, BSFC, higher FCE and lower emissions of CO, CO2, HC but more NOx compared to gasoline (Kalam et al, 2005). In another study that the direct and indirect (prechamber) spark ignition of the natural-gas engine by concerned engine parameters (spark timing and load) and turbocharger characteristics were compared. The main results showed that the indirect ignition 40 and 55% less CO and THC emissions, respectively. The delay of spark timing about 8^0 CABTDC was required for the prechamber ignition to reduce the cylinder pressure and decrease NOX, CO and THC. Using a turbocharger increased the fuel efficiency but also was caused an increase of approximately 40% in THC emissions (Roethlisberger and Favrat, 2002). From the review, CNG can be considered as a popular alternative fuel-and a lot of studies have been focusing on this subject. Hence, this study aims to present and analyze the performance and emissions of CNG and gasoline in gasoline engine port injection with different throttle positions.

Mohamad, T.I., H.H. Geok, S. Abdullah, Y. Ali and A. Shamsudeen, (2010) carried out a study on Comparison of performance, combustion characteristics and emissions of a spark ignition engine fuelled by gasoline and compressed natural gas and came out with the following conclusions: On average, Petrol and CNG produce more brake power, brake torque and brake mean effective pressure at wide throttle position. CNG operation produces less brake power, less brake torque and less brake mean effective pressure compare to gasoline. Results also show that BSFC of gasoline is less than CNG. The emission of NO and NOx of CNG is lower at low speeds and high speed but the emission increases at 3000-3500 rpm. The emissions of CO2 and CO were found less of CNG compared to gasoline.

ANDREW MACLEAN (2013) in his article reported that despite car makers spending billions developing electric cars, petrol-powered vehicles will still rule the roads by 2040 according to a report released to a report released by the US Energy Information Administration. During a press conference held in

Washington last week, the department's administrator. Adam Siemenski outlined that within the report it predicts 78 percent of vehicles in 2040 will still use a petrol-powered combustion engine – albeit a four percent reduction in comparison to today. The report said that, within that number, it predicts a significant rise in mild hybrid systems to improve fuel consumption with almost half to new cars sold in 2040 featuring some form of energy recovery technology. It predicts that full hybrid vehicle sales will almost double from three to five percent, with similar growth in diesel-powered vehicle sales-which is still relatively low in the US compared to Europe and Australia-with an increase from two percent today to four percent by 2040. It says full electric vehicles and plug-in hybrids which can run partially on electric power alone will only make up two percent of sales. The EIA last year predicted that motorists would increase their average yearly mileage by 41 percent in 2040, but has since revised that number to 30 percent. Despite the additional travel, it says the fuel consumption will continue to drop with the greater proportion of hybrid vehicles and continued improvements in efficiency for conventional engine technology. It predicts that average fuel consumption will drop from today's 10.9L/100km to 6.3L/100km-which is well below the US Government's mandate that car maker's produce an entire fleer of vehicles that average 4.3L/100km by 2025. The US Environmental protection Agency has confirmed the trend is heading in the right direction with all US-built cars in 2012 generating a record low in terms of average fuel consumption of 9.9L100km-a 10 percent improvement over the previous year and the biggest drop in fuel consumption over the last 30 years. As part of the ELA report, it also revised its prediction for fuel prices in 2040, dropping from its initial estimate of US$4.40/gallon to US$3.90/gallon on the back of increased domestic production.

Evans et al. (1984) determined the performance of gasoline and natural gas operations. The results showed that the brake power decreases by 11.3% with the natural gas operation compared to gasoline operation. The results also showed that the brake specific fuel consumption (BSFC) decreases with the natural gas operation. This is due to the higher heating value of natural gas fuel than that of gasoline fuel.

Raine and Jones (1990) measured the exhaust gas temperature, piston crown, spark plug body, exhaust valve and cylinder head temperature in natural gas and gasoline fuelled engine. The results showed that, at wide open throttle conditions and at stoichiometric fuel-air ratios, the temperature of combustion chamber for natural gas fuelling was lower than that for gasoline fuelling. The exhaust gas temperature was lower for natural gas operation than that for gasoline operation. The exhaust valve temperature with gasoline fuelling was higher than that with natural gas fuelling.

Gupta et al. (1996) investigated the performances and emissions of a spark ignited engine fuelled with gasoline and compressed natural gas. Results showed that for stoichiometric fueling, with a naturally aspirated engine, a power loss of 10 to 15 percent can be expected for natural gas over gasoline fueling. Higher brake thermal efficiencies can also be expected with natural gas fueling with maximum brake torque (MBT) timings over the range of equivalence ratios investigated in this work Coefficient of variation data based on the indicated mean effective pressure demonstrated that the engine is much less sensitive to equivalence ratio leaning for natural gas fueling as compared to gasoline cases.

Cho et al. (2007) reviewed some of the characteristics of combustion and emission of natural gas engine. They mainly focused on carbon dioxide, particulate matter, nitrogen oxides, unburned hydrocarbons, temperature of piston and cylinder head, valve seat temperature, MBT timing and equivalence ratio. Results showed that the combustion duration, the coefficient of variation of the indicated mean effective pressure and engineout emissions were dependent on the overall air fuel ratio, throttle positions and fuel injection timings.

R. Ebrahimi, M. Mercier (2010) did an experimental study of performance of spark ignition engine with gasoline and natural gas and made the following remarks: On average the results showed that natural gas operation causes an increase of about 6.2% in BSFC, 22% in water Temperature difference between outlet and inlet engine, 3% in exhaust valve seat temperature, 2.3% in BTE and a decrease of around 20.1% in MBT, 6.8% in exhaust gas temperature and 19% in lubricating oil temperature when compared to gasoline operating. The maximum of MBT, BTE, exhaust gas temperature and the minimum of BSFC at gasoline operation are found around equivalence ratio 1. 11, 1.0, 1.0 and 1.0, respectively and are found around equivalence ratio 1.06, 0.9, 1.0 and 0.9 for natural gas operation, respectively. It can be concluded that the equivalence ratio of maximum MBT is higher than equivalence ratio of maximum BTE for natural gas and gasoline operations. The BSFC depends on the heating value of the fuel rather than the MBT and BTE. The exhaust gas temperature of gasoline operation is higher than that of natural gas operation, while the exhaust valve seat temperature of natural gas operation is higher. Over the entire range of engine speed and equivalence ratio, the exhaust gas temperature and the lubricating oil.

Munde Gopal G., Dr. Dalu Rjendra S. (2013) carried out an experimental study on SI engine at different ignition timing using CNG and Petrol-20% in Butanol blend and came out with the following results: The BSFC for CNG is always less than that of the gasoline and slightly than the B20 . BSFC decreases with the increase in the load for the all fuels used. BTE increases with at all the loading conditions as BSFC decreases.

Thus CNG shows higher BTE as compared to B20 and Gasoline and B20 shows higher BTE as compared to Gasoline. Advancing the Ignition timing had decrease in exhaust gas temperature, Using B20 and CNG as a fuel exhaust gas temperature is more compared to gasoline at all Ignition Timing. CO emission goes on increasing with Ignition advancement but has minute variation; it is also observed goes on reducing with advancing the Ignition Timing, CO2 emission also has little variation with change in Ignition Timing, and it is observed that CO2 emission for gasoline is more compared to hat of CNG and B20. The percentage of Hydro carbon (HC) emission goes on increasing with advancing the ignition Timing, with increase in load there was reduction in Hydrocarbon emission., The hydro carbon emission for CNG was less compared to Gasoline and B20 at all Ignition Timing. It is observed that NOx emission was having low value at 270 BTDC using gasoline as a fuel, whereas for CNG and B20 also NOx emission was observed to be low at 320 BTDC, further advancing the Ignition timing had shown increase in NOx emission, it is found that NOx emission was more while using B20 as a fuel compared to that of Gasoline and CNG. Evaluating the performance characteristics on the basis of thermal efficiency, the experimental result showed the best performance using CNG as a fuel at 270 BTDC ignition timing. Whereas medium performance using B20 as fuel and poor performance using gasoline as a fuel at 270 BTDC ignition timing.

The most important effects on emission are injection time, natural-gas composition and initial temperature. Retarding fuel injection timing might reduce NO and increasing of ethane advance ignition and increase NO (Zheng et al., 2005).

Another experiment by Wang et al. (2007) was to study the combustion behaviour of the Direct Injection (DI) engine with various natural gas-hydrogen. The results were shown to increase in bake effective thermal efficiency with the increase of hydrogen fraction. Unburnt Hydrocarbons (HC) and CO2 decreased with the increase as the hydrogen and also NOx concentration increased with the increase of hydrogen fraction (Wang et al., 2007). Zarante and Sodre (2009) were evaluated carbon emissions by using natural gas as fuel. According to result's CO and CO2 were decreased when using natural gas compared to gasoline.

On the other hand, in a review study which focused on performance and emissions for natural gas fuelled spark-ignition and compression-ignition. The results were showing that natural gas can be used for both engines but improvement and optimization of engine are needed (Korakianitis et al., 2011).

Jahirul et al, (2010) compared the performance and exhaust emission on a gasoline and Compressed Natural Gas (CNG) fuelled spark-ignited engine at 50 and 80% throttle positions. Comparative analysis showed 19.25 and 10.86% reduction in brake power and 15.96 and 14.68% reduction in Brake Specific Fuel Consumption (BSFC) at 50 and 80% throttle positions, respectively while the engine was fuelled wit CNG compared to that with the gasoline (Jahirul et al., 2010).

Other studies were focused on the performance of natural gas using direct injection and compared with gasoline or diesel such as Kalam and Masjuk (2011) on the study "an experimental investigation of high performance natural gas engine with direct injection". Exhaust valve seat temperature for natural gas operation is higher. The exhaust valve seat temperature and the lubricating oil temperature are almost linear with the engine speed for natural gas and gasoline operation.

M.I. Jahirul, H.H. Masjaki, R. Saidur, M.A. Kalam, M.H. Jayed, M.A. Wazed (2010) carried out a comparative engine performance and emission analysis of CNG and gasoline in a retrofitted car engine and came out with the following conclusions: The CNG produces lower brake power than the gasoline throughout the speed range. Retrofitted car engine runs on lower BSFC when using CNG than on gasoline. The CNG has an advantage of higher brake thermal efficiency on an average of 1.1% and 1.6% than that of gasoline. The engine exhaust gas temperature produced by the CNG burning is always higher as compared with that of the gasoline. CNG fueled retrofitted car engine produced lower HC, CO, O2 emission throughout the speed range than gasoline. Higher NOx emission is the main emission concern for CNG as automotive fuel. 41% and 38% higher NOx emissions have been recorded at 50% and 80% throttle position respectively, compared to that of gasoline. Such a huge emission range should be a major environmental concern as CNG retrofitted automotives are now mass produced and used.

Liu Big et al. (2008) have studied the effects of hydrogen addition on the natural gas engine operation. According to their results, the combination of hydrogen and CNG/air mixture had injurious effect on the combustion delay and increased the burning rate

Performance and emission characteristics of a bi-fuel SI engine have been compare by AL-Baghdadi and AI-Janabi (2000). According to their results, the engine power and exhaust emissions are very lower in CNG fuelled engine.

Das and Reddy (2000) conducted the experiment on CNG bi-fuel passenger car and predicted the engine performance, fuel consumption and emission to reduce system calibration time as well as the cost of testing. According to their result, the carbon monoxide (CO) on CNG is very lower compared to petrol engine.

Manivannan et al. (2003) has studied the reducing of emissions with lean burn strategy for natural gas and also evaluated the emission characteristics with respect to their performance in spark ignition engines

In terms of brake specific fuel consumption (BSFC), emissions and brake thermal efficiency (BTE), a mixture of low hydrogen percentage is suitable for use (Orhan et al., 2004).

Renny and Janardan (2008) stated that a reliable performance and safe operation with enhanced fuel efficiency, better acceleration and lower exhaust emissions was achieved with hydrogen-CNG blended fueling of a CNG three wheeler.

According to Sierens and Rosseel (1995), besides economical reasons, CNG is an attractive fuel for vehicles because it is a relatively clean burning fuel as compared to gasoline. BTE increases as power increases, reaches to maximum and then decreases for higher increases of power; which is observed for all blends.

Sorensen (2005) reported that hydrogen is a useful additive for natural gas that enables leaner operation under part load conditions and improves brake mean effective pressure (BMEP) at wide open throttle near the lean limit. Moreover, NOx values are reduced, if normal hydrocarbon emissions or fuel consumptions observed with natural gas are not exceeded.

M.M Gossal*, L.M. Das and M.K Gajendra Babu (2013) carried out a research on improved efficiency of CNG using hydrogen in spark ignition engine and came out with the following conclusions: A better or comparable performance was obtained with about 20 to 30^0 by volume wise substitution of hydrogen fuel under all load conditions. Brake thermal efficiency increases by 20% and brake specific energy consumption values decrease by 14% with increasing hydrogen HC and CO emissions values decrease by 30% and 80% respectively.

According to M.I. Jahirul, (2010) the compressed natural gas vehicles exhibit significant potential for the reduction of gas emissions and particulate. There are any problems for compressed natural gas applications such as onboard storage due to low energy volume ratio, knock at high loads and high emission of methane and carbon monoxide at light loads. However, these can be overcome by the proper design, fuel management and exhaust treatment techniques.

M.K Hassan, I.Aris, S..Mahmod, R. Sidek [2010] worked on Experimental investigations of performance and exhaust gases, concentration at various ignition and injection timing for high compression engine fuelled with compressed natural gas (CNG) engine. The engine implements central direct injection (DI) method. All injectors are positioned within a certain degrees of spark plug. It is called as CNGDI engine. The results showed that, CO concentration occurs at late injection timing and the lowest emission is 0.011% when we applied 300 bTDC ignition at 3600 CA injection timing.

M.I Jahirul et al [2010] have worked on Comparision engine performance and emission analysis of CNG and gasoline. The test was carried out with in a retrofitted car engine use a 1.6.L,4- cylinder petrol engine was converted to the computer incorporated bi-fuel system which operated with either gasoline or CNG using an electronically controlled solenoid actuated valve mechanism. The engine or CNG using an electronically controlled solenoid actuated valve mechanism. The engine performance and exhaust emission was measured over a range of speed variations at 50% throttle positions.. The results showed that, 19.25% and 10.86% reduction in BP and 15.96% and 14.68% reduction in BSFC at 50% and s0% throttle positions respectively while the engine was fueled with CNG compared to that with the gasoline. Other emission contents (unburnt HC, CO, O2 and CO2) were significantly lower than those of the gasoline emissions.

E. Ramjee and K. Vijaya Kumar Reddy [2011] worked on experimental investigations on a single cylinder 4-stroke air cooled type Bajaj-Kawasaki petrol engine to compute performance and exhaust emissions of the test engine. All tests have been carried out under steady state conditions for both petrol and CNG fuels and the results have been compared. They found that for all range of speeds, the volumetric efficiency is reduced and various between 10-14%; Except thermal efficiency the other performance parameters viz BMEP, Torque, Power and BSFC are decreased for CNG fuelled engine compared to petrol fuelled engine; Except NOx the other emission characteristics such as CO, CO2, and HC are decreased.

Pravin T. Nitnaware, Jiwak G. Suryawanshi [2011] the main purpose of the researches to obtained design and improve low flame propagation and poor combustion stability of Natural Gas fuelled engine and investigate the combustion behaviours of sequential gas injection in multi-cylinder SI engine operation. In this research, experiments were carried out to obtained the results from running a 3-cylinder spark ignition engine with gasoline and compressed natural gas (CNG). They found that on average CNG yielded 19% less BSFC, Compared to gasoline. However, the volumetric efficiency was reduced by 5-17% with CNG operation. Due to this, the brake torque, brake power and brake mean effective pressure of the engine were reduced by 8-16%. In terms of exhaust emissions, WOT results showed that HC, and CO2 were significantly reduced compared to gasoline.

Reji Mathai, R.K. Malhotra, K.A. Subramanian, L.M.. Das [2012] have worked on the effect of compressed natural gas (CNG) and 18% hydrogen blended compressed natural gas (HCNG) on a retrofitted gasoline genset engine "s performance, emissions, deposits and lubricants under long duration testing. The test was carried out with a Honda twin-cylinder water cooled gasoline engine. The results showed that, HCNG fuelled engine decreased BSFC, CO and HC emissions with penalty of NOx emission. HCNG operation significantly reduced the kinematic viscosity and TBN and increased wear metal of Fe and Cu in lubricant. After the 60h of tests gaseous fuels did not show any abnormal wear or deposits on engine components. Higher deposits of Iron on the spark plug and Iron oxide on the cylinder liner are observed for HCNG fuel.

In area of increasing volumetric efficiency, Fanhua Ma et al [10] developed an electronically controlled natural gas fuelled engine with a turbocharged spark-ignition natural gas engine controlled by an electronic control. The experimental data was taken at hydrogen fractions of 0%, 30% and 55% by volume and was conducted under different excess air ratio (1) at MBT operating conditions system. It is found that under various results the addition of hydrogen can significantly reduce CO, CH4 emissions and the NOx emission remain at an acceptable level when ignition timing is optimized. Using the same excess air ratio, as more hydrogen is added the power, exhaust temperatures and max cylinder pressure decrease slowly until the mixture "s lower heating value remains unchanged with the hydrogen enrichment, then they rise gradually.

Munde Gopal G., Dr. Dalu Rajendra S. (2012) carried out a review on compressed natural gas as an alternative fuel for spark ignition engine and came out with the following remarks: The engine thermal efficiency and exhaust gas temperature produced by the CNG burning is always higher as compared with that of the petrol. CNG produces less than 8-16% of effective brake torque, brake power and BMEP compared to gasoline fuel due to reduced volumetric efficiency and lower flame speed of CNG. On average the reduction of CO, CO2 and HC emission are 20-98%, 8-20% and 40-87% respectively by CNG. Higher NOx emissions is the main emission concern for CNG as automotive fuel that can be reduced by increasing fuel density and blending small quantities of H2.

Renny and Janardan (2008) stated that a reliable performance and safe operation with enhanced fuel efficiency, better acceleration and lower exhaust emissions was achieved with hydrogen-CNG blended fuelling of a CNG three wheeler.

Table 1. Petrol Composition

COMPONENT	SYMBOL	MASS FRACTION *100
Component	C	85.34
Hydrogen	H	13
Oxygen	O	1.4
sulphur	S	0.00

Table 2. Thermodynamic Properties of Petrol

Stoichiometric ratio	14.2
Octance Number	96
Higher Headting Value (MJ/Kg)	54
Lower Heating Value (MJ/Kg)	42.2
Density @25^0c (Kg/m^3) (DIN 51757)	749
Molecular Weight (Kg/Kmol)	106.2

Table 3. Thermodynamic Properties of Natural Gas

Stoichiometric ratio	15.7
Higher rating value (MJ/Kg)	50.3
Lower heating value (MJ/Kg)	45.9
Molecular Weight (Kg/Kmol)	17.74
Octance Number	120
Methane	69-99

Table 4. Natural Composition

Component	SYMBOL	VOLUMETRIC %
Methane	CH4	89.4
Ethane	C2H6	4.6
Propane	C3H8	1.0
Butane	C4H10	0.3
Pentane	C5H12	0.0
Hexane	C6H14	0
Carbon dioxide	C02	0
Nitrogen	N2	4
Oxygen	O2	0

TABLE 5. Variations of Engines Performance Parameters

Items	Petrol	CNG
Max. Power (KW)	6.20@5000RPM	5.34@5000RPM
Max. Toque (Nm)	8.35@2500rpm	7.13@2500rpm
Max. Volumetric Efficiency	89.51@4000rpm	77.59@400rpm
Max. Thermal Efficiency %	34%@2500rpm	98%@2000rpm

II. The Evaluation

- **Evaluation based on Performance:** CNG burns at a high octane rating of 130 and performs better than Petrol powered vehicles under cold start conditions. CNG Vehicles have better horse power and cruise speed just like petrol. In terms of Kilometers (Km) per litre, a light duty Compressed Natural Gas Vehicles will get about the same Km per equivalent litre of Natural Gas as it does on Petrol. CNG provides easy starting, reliable idling and smooth acceleration. When CNG vehicles are running, its acceleration is a bit slower due to loss of Power typically 5-15% which can be minimized by proper tuning on the CNG Kit (e.g advancing the spark timing) to take advantage of the high octane rating of the fuel. The power loss on CNG is not noticeable in ordinary city driving.
- **Evaluation based on Storage and Safety:** Firstly, CNG has four big safety features that make it an inherently safer fuel than petrol: CNG has a specific gravity of 0.587 which means that it is lighter than air so if it leaks, it just rises up and dissipates into the atmosphere. Secondly, CNG has a self-ignition temperature of 700 degree centigrade as opposed to 455 degree centigrade of petrol. Thirdly, CNG has to mix air within small range of 4 to 14% by volume for combustion to occur. This is far narrower range than petrol. Fourthly, CNG cylinders are designed and built with special materials to the highest safety specification which make storage far safer than petrol tanks. The CO on CNG is very lower compared to petrol and it's a relatively clean burning fuel as compared to petrol.
- **Evaluation based on Maintenance:** The recommended maintenance scheduled for CNG vehicles are similar to those for petrol fueled vehicles because CNG burns clearly than petrol, CNG powered vehicles requires less maintenance, including fewer oil changes and less frequent spark plug replacement. High pressure tanks require periodic inspection. CNG vehicles are equipped with high pressure storage tanks capable of storing CNG to about 200bar.
- **Evaluation based on Emissions:** CNG burns more completely than petrol and emits lower amounts of all the regulated exhaust pollutants. Carbon dioxide emissions are also lower in CNG than emissions from petrol powered vehicles, but methane levels are higher. Methane's ability to trap heat in the atmosphere or its global warming potential is 21 times greater than that of carbon dioxide.
- **Evaluation based on Economy and Cost:** Currently, all alternative fuelled vehicles have a price premium over traditional fuelled vehicles (unless manufacturers have special promotional prices that they subsidized). With more vehicles coming into the market, certain economies of scale will be achieved. The price of a CNG vehicle varies depending upon whether it is a petrol vehicle converted to run on CNG or a factory built vehicle. Different size vehicles also vary in price, typical seldom are less expensive and trucks, which requires more storage cylinders are more expensive. CNG vehicle conversion equipment can be purchased for about €4000 (4000 Euro) and installed by fleet owners who can receive training from the conversion companies or conversion kit manufacturers. Alternatively, CNG vehicle specialist can do the conversion which adds about 25% to the vehicle cost. Larger vehicles requires more fuel storage cylinders and the price can increase depending on how many cylinders and the type installed. Light duty CNG vehicles from the factory can range in price from €1000 - €6000 over the price of a traditional fuelled vehicle. Heavy duty engines, trucks and buses typically cost €30,000-€50000 more than standard petrol engines and vehicles.
- **Evaluation based on Technology:** There are some recent important advances in CNG vehicle technology that will keep the industry on track with the most advanced technologies being produced by the major automotive manufacturers. CNG vehicles now are compatible with computerized fuel injected engines. They are superior to petrol vehicles because CNG is injected directly into the combustion chamber in its gaseous state without having to go through a special gas/air mixer. The newest system are "closed loop", they are part of the systems that include oxygen sensors in the vehicle tail pipe, and provides feedback to the engine control systems to alter the fuel/air ratio depending upon the requirements of a vehicle's performance at any given time.
- **Evaluation based on refueling of the Vehicles:** Natural gas is compressed and vehicles can be refueled directly from the compressor on a slow fill basis (about five to eight hours) or can be refueled in one to two minutes using compressed gas stored in cascades of CNG cylinders (multiple gas cylinder interconnected). Many privately owned refueling stations use a combination of fast fill and slow fill, depending upon the individual needs.
- **Evaluation based on fueling station cost:** Installation of a compressor station to refuel the CNG vehicles is an additional expenses, if public refueling is unavailable. Some utilities are providing compressor station equipment free, or are making special arrangements with fleet operators to provide the Natural Gas in the form it is used-compressed. Depending upon the design of the station, the number of vehicles to be refueled and

fuel storage requirements, compressors and related equipment can cost from €5000-€10000 (for small compressors) to €40000 or more for stations capable of serving hundreds of vehicles. Bus fueling stations, where 3 minutes quick fill is required for large numbers of vehicles can cost €1 million or more. For normal fleet vehicles, however as a general rule, you can expect to spend €1000-€2000 per vehicle to install a fueling station.

- **Evaluation based on engine conditions:** CNG has no harmful effect on the engine. On the contrary, the life of an engine increases by using CNG. Lubricating oil life is extended considerably because CNG does not contaminate and dilute the crankcase oil. Due to the absence of any lead content, lead fouling of plugs is completely eliminated and the plug life is greatly extended. Another aspect which increases engine life is that, CNG enters the engine in the form of a gas whereas petrol enters in the form of spray or mist. This spray/mist washes down the lubricating oil from the piston rings and thereby increases the rate of depreciation of the engine. Since this is not the case when using CNG, the life of the engine is increased, on the whole, the maintenance costs are reduced and engine life is increased.
- **Evaluation based on legislations and incentives:** incentives encouraging the use of CNG vehicles differ by country. For example: there are special tax provisions that reduce fuel taxation in Germany, Sweden, and the UK, in Belgium, Ireland , and Italy there is no fuel tax on Natural Gas as a vehicle fuel, making it economical compared to other competitive fuels. In Germany, the Ministry of the Environment ran a competition worth DM5 million, which it awarded to the city of Augsburg as a promotion for CNGVs. Other incentive programs are developing slowly in Europe.
- **Evaluation based on the market place:** The most important element missing in the market place is deep enthusiasm on the part of the majority of the Natural Gas industry, which would rather market to the "big pipe" customers like co. generators than work to diversify into a vehicle transportation market of smaller customers looking for Environmental friendly ways to stay economically competitive. The CNG vehicle business today could very well pave the way into the twenty first century when fuel cells might be a major market contributor to cleaner vehicles of tomorrow fuelled by hydrogen reformed from Natural Gas. Unfortunately, many Gas Company Executives look out onto a parking lot filled with petrol and diesel vehicles instead of CNGVs. When it comes to the CNGV market of the twenty first century, too many of these same Executives are peering into the future through the wrong end of the binoculars.
- **Evaluation based on adequacy of fuel supply:** Natural gas (CNG) is very adequate for S.I engines due to its octane number as drawn from sermin (2009) research work.
- **Evaluation based on process efficiency:** The results from Mr. Saravanan V.D. Dr. P.S Utgika (2013) and mardani Ali sera (2008) research showed that, CNG has low volumetric efficiency due to low density and under the same engine operations and configurations, CNG shows 20% reduction in Mechanical efficiency. But Kalam et al (2005) says there will be increase in efficiency when a turbocharger is used with a corresponding increase in emissions.

Limitations Delaying The Full Utilization Of Cng As Vehicular Fuel:

- Cost of vehicle is very high
- Refueling infrastructure
- Component availability
- Financial requirement
- Loses in volumetric efficiency
- Low flame speed
- Low compression ratio
- Absence of fuel evaporation
- Change in stoichometric air/fuel ratio
- The cost and replacement of fuel storage tanks
- Require a greater amount of amount space for fuel storage than petrol vehicles
- Refueling time is longer
- It can cause back fire in the inlet manifold

III. Recommendation

For CNG to be a better choice over petrol without any delay in the utilization, the following suitability factors must be considered:

- Fuel reserves
- Refueling infrastructure
- Component availability
- Emission potential

- Safety
- Financial requirement

IV. Conclusion

The main focus of this review work was to evaluate the comparative analysis of previous work done in the use of CNG and Petrol as vehicular fuel and as a result, the following conclusions were drawn as follows:

- CNG has low Volumetric Efficiency and 20% reduction in Mechanical Efficiency.
- CNG has no harmful effect on the engine and it si very adequate for S.I engines
- CNG burns more completely than petrol and emits lower amounts of all the regulated exhaust pollutants.
- CNG powered vehicles requires less maintenance, including fewer oil changes and less frequent spark plug replacement.
- It can be concluded that CNG vehicles have better horse power and cruise speed just like petrol
- CNG has higher engine thermal efficiency and exhaust gas temperature
- CNG produces less than 8-16% of brake torque, brake power and BMEP compared to petrol due to reduced volumetric efficiency and lower flame speed of CNG
- CNG has 19% brake specific fuel consumption (BSFC) compared to petrol

References

[1]. E. Ramjee and K. Vijaya Kumar Reddy (2011) performance analysis of a 4-stroke SI engine using CNG as an alternative fuel. Indian Journal of Science and Technology (2011-04-07).

[2]. Al-Baghdadi Mars and Al-Janabi HAKS (2000) Improvement of performance and reduction of pollutant emission of a four stroke Spark Ignition engine fuelled with hydrogen gasline fuel mixture. Energy Conversion & Management, 41,77-91.

[3]. Aslam Mu, Maojuki HH, Kalam MA, Abdesselam H, Mahila TMI and Amalima MA (2006) An experimental investigation of CNG as an alternative fuel for a retrofitted gaxline vehicle. Fuel Process Technol. 85, 717-724.

[4]. Chiodi M, Berner H and Barragende M (2004) Investigation on mixture formation and combustion process in a CNG engine by using a fast response 3D-CFD-Smulation. SAE Technical paper 2004-10-3004.

[5]. Das LM and Reddy YV (2000) Exhaust emission Characteristics of a CNG-Fuelled engine, Pro 16th Nat cont IC engines combustion Jadavpur Univ.

[6]. Liu Bing, Huarg Zuohua, Zeng Ke, et al (2008) Experimental Study on emission of a Spark-Ignition engine fuelled with natural gas-hydrogen blends. Engergy & fuels 22 (1), 273-277.

[7]. MANWANNAN A, Tamii Pp, Chandrasekan S. and Ramprabhu R (2003) lean burn natural gas Spark Ignition engine-An overview. SAE Paper NO. 2003-01-0638.

[8]. Bielaczyc, P. Paydowski, P. and seczotka, A Comparision of gaseous pollutants and particulate matter emission from vehicles with SI and CI engines with different fuels and fuel delivery systems. SAITS 01193, European Automotive Congrers EAEC 2001, B ratislava18-20 june 2001