Influence of Ignition Energy on the Performance of Bi-Fuel Engine Using CNG as Alternative Fuel : A Review

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Abstract

It is well known, that fossil fuel reserves all over the world are diminishing at an alarming rate and a shortage of crude oil expected at the early decades of this century. Probably in this century, it believed that crude oil and petroleum products become very scare and costly to find and produce. Alternative fuel technology, availability and use must and will become more common in the coming decades. Nowadays in automotive industry, the applying of gaseous fuels and particularly compressed natural gas both in SI and CI engines is more frequent. Application of CNG in the spark ignition internal combustion engines is more real than never before. Most of its used is limited to retrofitted engines by conversing Bi-fuel engine. It is found that power produced by such Bi-fuel engine in CNG mode is found 14-18% less than gasoline mode. Because of the low volumetric efficiency, low compression ratio, low spark energy, and not sufficient spark advance in the bi-fuel engine. In this paper influence of ignition energy on the performance and emission is discuss. It is found that increasing the ignition energy one can increase the lean combustion capacity. And also increase in the performance and emission of the Bi-fuel engine in CNG mode comparable to petrol mode. . Objective of this study is to capability utilisation of CNG in Bi-fuel with little modification in ignition energy.

1. Introduction

It is well known that fossil fuel reserves are becoming exhausted at an alarming rate. Moreover, the combustion of such fuels results in the emission of noxious pollutants which threaten the very survival of life in this planet. The role of existing internal combustion engines needs to be reviewed now in the context of these two major crises. Over the past decade, alternative fuels have been studied for the possibility of lower emission, economy, better (more secure) fuel availability and lower dependence on crude oil generated fuels. Before any alternative fuels could be used as an alternative to petrol or diesel, it has to full fill some criteria. Rosli Abu Bakar has listed some suitability factors that would support alternative fuel to become a choice over petroleum fuels Fuel Reserves, Refuelling infrastructure, Component availability, Emission potential, Safety, Financial requirement.

CNG (compressed natural gas), a gaseous form of natural gas, clearly has some substantial benefits compared to gasoline and diesel. These include lower fuel costs, higher octane and, most certainly, cleaner exhaust emissions. As a result, CNG as a fuel is clean, economical and has been in use worldwide to power vehicles. CNG is colourless, odourless, non-toxic, lighter than air and inflammable. There are over 1,500,000 vehicles in the world produced by Honda, Ford, Toyota, Volvo, Mercedes Benz, Optare, Iveco, Cummins and Scania running on CNG. [1] Exhaust emissions from CNG fuels are much lower than those from petrol/diesel powered engines. Per unit of energy, natural gas contains less carbon than any other fossil fuel, and thus produces lower level of CO2. CNG was used with methane gas, about 80–90% per volume, and methane gas was excepted from HC emission count because it is harmless for living things [2]. The CO and NMHC (Non Methane Hydro Carbon) emissions from the engine running on natural gas are lower than those of an engine running on gasoline under similar conditions.

Table 1. Properties of Gasoline and CNG.

Properties	Gasoline	CNG
Density Kg/m^3 (25ºC)	730	0.66
Boiling Point (ºC)	27-225	-162
Flame Propagation(m/s)	0.5	0.43
Octane Number	92-98	120
Stoichiometric air-fuel ratio	14.6	17.3
Lower heating value(MJ/kg)	43.6	47.37
Flammability limits	13-7.1	5-15
Spontaneous ignition temperature(ºC)	257	540

Now a days CNG is used in the gasoline engine by retrofitting aftermarket or company fitted CNG kit. All engines are converted in to Bi-fuel engine by retrofitting. SI engine are more suitable with Bi-fuel conversion with CNG as second fuel. Bi fuel engine use either of petrol or CNG as fuel by switch operate by driver or automatic in vehicle.

CNG used in IC engine

Almost any petrol engine can be converted to operate on CNG with special Kit fitment. Diesel engine can also be converted on CNG either by installing dual fuel kit or converting the existing into spark ignition engine. But it is costly to convert in Spark ignition and skill require for that. Natural gas has considerably higher octane number than petrol and has very low Cetane number when compared with diesel fuel. Hence it is more suitable for SI engine rather than CI engine. Bi-fuel vehicle can run on either natural gas or petrol.

Bi-Fuel: Bi-fuel systems are also called "switchable" systems because you can switch between gasoline or CNG. Most conversions we do for light duty (new or used trucks) are bi-fuel because they give the customer the best of both worlds. You can run on CNG as long as you have fuel in the tank and switch over to gasoline if you run out. Most modern bi-fuel systems are fully automated, switching to gasoline when they need to and then automatically switching back once the CNG tank is filled. Bi-fuel vehicles come equipped with two fuel gauges and a switch to move from CNG to gasoline if the driver desires. This type of engine development is based on the conventional petrol engines where the fuel system has been modified to operate either petrol or gas. When natural gas refuelling is not available, normal running on petrol is possible.[3]

Dual Fuel: This is a development from conventional diesel engine. In this type of engine, both diesel and natural gas were introduced into the engine cylinders during compression. As natural gas will not ignite under compression alone, the diesel is required to act ignite the gas/air mixture. When natural gas refuelling points are not available, the engine can revert to conventional operation. [3]

Dedicated/Single Fuel: This is a specialized engine type, which has been designed and optimized to operate only on natural gas. This enables the characteristics of natural gas to be fully exploited without the need to compromise in design to enable other fuel usage.[3]

Retrofitted NGV engines, however, produce about 10–15%[2] less power than the same engine fuelled by gasoline. Another main drawback is the heavier fuel storage tank and vehicle range is compromised for avoiding very large storage tank. By using CNG in Bi-fuel engine Emission and thermal efficiency 18-22% is increases and BSFC is decreases. But volumetric efficiency 12-18% decrease and hence power output also decrease nearly 14-20 %[2]. This loss in the power is mainly due to less of capability utilisation CNG. There are various parameters which can affect the performance and emission of the CNG bi-fuel engine. Like compression ratio, spark advance, ignition energy, inlet valve opening, and equivalent ratio.

There are various research is going on the ignition parameters like Ignition Advance, Spark plug electrode size, Spark gap width and spark projection, Spark plug intensity and also on the spark electrode material. By increasing spark energy increase the lean burn capacity of engine. Lean burn is an effective way to improve fuel efficiency and reduce NOx emissions. Spark energy can be improve various ways plasma jet igniters, rail plugs, photochemical devices, lasers, microwave concepts, torch cells, divided chamber stratified charge engines, flame jet igniter.[8] Now days many parameters of spark plug are studies to increase the ignition energy. By increasing the dwell time ignition energy increases, decreasing the electrode diameter and also changing the shape of the electrode increase ignition energy, by increasing the gap of the spark plug ignition energy increases. [9]

Effect of ignition energy in Bi-fuel CNG engine

According to semin and rosli abu bakar[2] CNG is attractive for five reasons. It is the only fuel cheaper than gasoline or diesel. It has inherently lower air pollution emissions. It has lower greenhouse gas emissions. Its use extends petroleum supplies, and there are large quantities of the fuel available in the world. As CNG has a higher octane rating 130 higher compression ratio can be used compare to petrol to improve thermal efficiency by 10%. Optimize CNG engine should be up to 20% more efficient. Optimum efficiency from natural gas is obtained when burnt in a lean mixture in the range A=1.3 to 1.5, although this leads to a loss in power. Natural gas must be in a concentration of 5% to 15% in order to ignite.

Mr. Saravanan V.S et al.[4] converted 0.8 litre multipoint fuel injection engine into CNG bi-fuel sequential type port fuel injection. 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. In terms of exhaust emissions, the results will be that HC, CO and CO2 will be significantly reduced by 40-66%, 55-87% and 28-30 % respectively compared to gasoline.

A.S. Atkar et al.[5] an experimental study was conducted on a conducted on a carburetted 2-stroke gasoline, 3-wheeler engine for operating on CNG in Bi-fuel mode and further on dedicated CNG. Power drop for Bi-fuel mode at different speeds for full throttle condition on CNG is from 14-19%. This is because of less volumetric efficiency of CNG compared to Gasoline. Power drop for dedicated CNG engine is 8% compare to gasoline mode. It is found 8-9% increase in power in dedicated CNG compare to Bi-fuel mode.

ABIANEH et al.[6] The minimum spark energy required for methane ignition is markedly higher than for other hydrocarbons. As a result, the conversion of an engine to natural gas requires a high performance ignition system. It was also observed that the required energy for pure methane is 100 to 120 mJ. Methane also has a wider flammability. This allows an engine to operate on a lean mixture. If is found that by using CNG power reduces compare to gasoline engine because of low volumetric efficiency The volumetric efficiency is reduced because of the gaseous state of the fuel. Haeng Muk Cho et al.[7] explain effect of lean burn on the performance and emission. Homogeneous lean burn mixtures result in lower flame propagation, occurrence of misfire, low mixture distribution quality in multi-cylinder engines and high unburned HC emissions in the exhaust. To implement successfully a lean burn strategy to natural gas engines with minimum exhaust emissions and maximum thermal efficiency, high compression ratio, high energy ignition system, increased swirl and turbulence at the end of the compression. Lean burn is an effective way to improve fuel efficiency and reduce NOx emissions.

Pankaj Rajput and Shreya Singh[8] say that Most of the automotive systems employ conventional conversion kits to run Gasoline engine on CNG. However, majority of these kits are incapable of tapping the potential of CNG as a spark ignition fuel. They used simulation model for the performance optimization. After several design iterations the following changes were incorporated in the existing computer model. CR increased from 11 to 15, Inlet port Diameter increased from 28 to 35, IVO changed from 15° BTDC to 25° BTDC, Spark advanced to 20° BTDC, Equivalence Ratio increased to 1.6. They found that power is increase from 80kw to 115kw at 600 rpm. However conventional conversion kits are unable to tap the high calorific value of CNG and hence the power in CNG mode is less compare to CNG mode.

J.D. Dale et al.[9] suggest that if alternative fuels are to be developed further and if high compression, lean burn technology is used for future fuel efficiency improvements, then higher energy and possibly enhanced ignition systems will be necessary. There are several short term and long term possibilities. The short term could use multiple spark plugs with conventional coils or breakdown (short duration, high power) systems. For the long term, it is suggested that more work be done on understanding the chemical kinetics of ignition processes which might lead to new concepts in ignition systems similar to the homogeneous ignition systems.

Jeonghoon Song et al. [10], suggest that change in the electrode gap, material, diameter and shape effect on flame kernel formation and development. when the spark plug gap is Extended from 0.8mm to 2.0mm, the discharged energy is increased by 74~93% according to ignition systems. As the gap is extended, the volume of plasma also increased and to sustain the expanded plasma, increased ignition energy is required. The diameter of electrode also influences on the discharged energy and on the growth of flame kernel. As the diameter is decreased from 2.8mm to 1.2mm, the discharged energy is increased by 1.6mJ from 15.1mJ. As the electrodes tip becomes sharper, the discharged energy is increased, and the current density is raised. The material of electrode affects on the ignition energy and flame propagation, which is closely related with its melting temperature. The lower melting temperature material yields higher ignition energy and higher transfer efficiency.

Table 2 Effect of spark gap on energy [13]

Spark Gap(mm)	Energy in direct ignition system(mJ)	Energy in high energy ignition(mJ)
0.8	11.8	20.3
1.2	15.8	29.1
2.0	20.5	39.2

Table 3. Effect of electrode diameter on ignition energy [13]

Spark Diameter (mm)	Energy in direct ignition system(mJ)	Energy in high Energy ignition(mJ)
1.2	16.7	30.8
2.0	15.8	29.1
2.8	15.1	27.1

As per Wadysaw Mitianiec[11] SI engine fuelled by CNG with lean homogeneous mixtures (λ=1.4) show that it causes a faulty ignition of charge. A bigger ignition temperature for the natural gas (640–670ºC) than for gasoline vapours (220°C) is required. For this reason for ignition of the gasoline-air mixture much lower energy is needed than for ignition of CNG-air mixture. Higher pressure of the air-methane mixture required also higher electric energy in the secondary circuit of the ignition coil and maximum high voltage peak increases with the charge pressure. As using CNG ionization of the spark gap has higher resistance than petrol. Hence the charged CNG spark ignition engines should be equipped with the high energy ignition system above 60 mJ given during period above 1 ms.

Conclusion

Conclusion Based on the reviews it is found that compressed natural gas is best alternative for the current IC engines. CNG reduced emission like HC, CO2, and CO considerably. It is beneficial and less costly to convert SI engine compare to CI engine in to CNG engine. Now a day's most of vehicle converted in CNG by Bi-fuel technology which can be done by retrofitting or company fitted CNG kit. However, majority of these kits are incapable of tapping the potential of CNG as a spark ignition fuel.it is found that power produced by the CNG 14-18% less compare to petrol engine and efficiency is reduce up to 20%. To increase the performance compatible to petrol various parameters which affect the performance should be optimized.

- Lean burn is an effective way to improve fuel efficiency and reduce NOx emissions. Lean burn limits are dependent on combustion chamber geometry, ignition timings, ignition energy and turbulence.
- It is found that minimum spark energy required for pure methane ignition is 100 mJ to 120mJwhich is higher than the gasoline. So the conversion of an engine to CNG engine requires higher performance ignition system. As using CNG ionization of spark gap to create spark has higher resistance than using petrol as fuel hence higher ignition energy is require ionizing spark gap.
- As CNG have low flammability speed, higher ignition temperature and higher pressure than petrol higher ignition energy require than petrol.
- Ignition energy can be increase various way by increasing the spark gap, by reducing the spark plug electrode diameter, by changing the spark plug electrode material and by giving different shape to electrode, increasing capacity of ignition coil, using multiple spark plug.

By increasing the ignition energy lean burn capacity of the fuel can be increase and performance of Bi-fuel engine in CNG mode can be compatible with petrol mode performance and capability utilization of CNG is possible. The scope of this review is by changing the ignition energy by any method of above keeping other parameter optimum one can increase the performance of the CNG in the Bi-fuel mode which compatible with petrol performance.

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References

[1] Munde Gopal G., Dr. Dalu Rajendra S. "Compressed Natural Gas as an Alternative Fuel for Spark Ignition Engine: A Review" IJEIT, Volume 2, Issue 6, December 2012.pp.92-96.

[2] Semin, Rosli, Abu Bakar "A Technical Review of Compressed Natural Gas as an Alternative Fuel for Internal Combustion Engines" American J. of Engineering and Applied Sciences 1(4): 302-311, 2008, ISSN 1941-7020.

[3] D.M Dave, Prof. M.A. Shaikh "Effect of ignition parameter for enhancement of performance and emissions of a four stroke single cylinder SI engine fuelled with CNG technical review" IJERT, ISSN:2278-0181, Vol.2 Issue4, 2013.

[4] Mr. Saravanan V.S , Dr. P. S. Utgikar, Dr. Sachin L Borse "Experimental Study on Conversion of 4 Stroke Gasoline Internal Combustion Engine into Enriched Compressed Natural Gas Engine To Achieve Lower Emissions" IJERA, Vol. 3, Issue 4, Jul-Aug 2013, ISSN: 2248-9622. pp.1103-1110

[5] A.S. Atkar, V.J. Tandan, S.D.Rairlkar, C.K. J Nair and M. K. Chaudhari "Development aspect of conversion of 2-stroke Gasoline Engine to Operate on Bi-fuel CNG and Dedicated CNG mode"Siat'96, Organised By ARAI pp.111-117

[6] O. S. Abianeh, M. Mirsalim and F. Ommi "Combustion Development of a Bi-fuel engine" International Journal of Automotive Technology, Vol. 10, No. 1, pp. 17−25 (2009).
[7] Haeng Muk Cho, Bang-Quan He "Spark ignition natural gas engines—A review" Energy Conversion and Management 48 (2007) 608–618, 2006.
[8] Pankaj Rajput, Shreya Singh "Optimization of Gasoline to CNG Engine Conversion using Computer aided Engine Simulation" IJERA ISSN: 2248-9622, Vol. 3, Issue 2, March -April 2013, pp.1429-1433.
[9] J.D. Dale, M.D. Checkela and P.R. Smyb "Application of high energy ignition systems to engine" Prog. Energy Combusr. Sci. Vol. 23. pp. 379-398, 1997 Elsevier Science Ltd.
[10] Jeonghoon Song, Youngho Seo, Myoungho Sunwoo. "Effects of Ignition Energy and System on Combustion Characteristics in a Constant Volume Combustion Chamber" Seoul 2000 FISITA World Automotive Congress, June 12-15, 2000,pp.1-6.
[11] Wadysaw Mitianiec "Ignition of CNG mixtures in spark ignition engines" Journal of KONES Powertrain and Transport, Vol. 19, No. 3 2012 pp. 297-304
[12] Jahirul M.I., Masjuki H.H., Saidur R., Kalam M.A, Jayed M.H., Wazed M.A. "Comparative engine performance and emission analysis of CNG and gasoline in a retrofitted car engine." Applied Thermal Engineering 30 (2010) 2219-2226.
[13] Heywood JB. Internal Combustion Engine Fundamentals. Singapore: McGraw-Hill; 1988 p 915.
[14] Vina Chauhan, P. M. Geroge & M.Y. Vaijanapurkar "Experimental Investigation of fuel consumption and efficiency of MPFI engine fuelled by Gasoline and CNG" Indian Journal of transport Management, 2010.
[15] Dr Gunther Herdin, DI Johann klausner "Laser Ignition- A new Concept to Use and Increase the Potentials of Gas Engines" ASME internal Combustion engine division 2005 Fall Technical Conference. 2005,Canada.
[16] Richard "Introduction to Internal Combustion Engines" 2nd Edition, The Macmillan Press Ltd,1992.