# To Study on The Performance and Emission of 18% H-Cng (Hydrogen Blended Compressed Natural Gas) on A Bi-Fuel Engine

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***Abstract: The continuous deterioration in reserves of fossils fuels, foreign exchange expenditure for import of crude petroleum, the unsteadiness of their prices and the increasingly stricter exhaust emission legislation, put forward the alternative fuels as substitute for the vehicles. Much interest has been laid down on CNG due to its potential for low particulate and hydrocarbon emissions. To improve low burning velocity and poor combustion stability of Natural gas fueled engine Hydrogen blending with CNG is looked upon as a good alternative fuel. The maximum mean gas temperature and maximum rate of pressure rise increased remarkably when the hydrogen volumetric fraction increase slightly. The burning velocity increases exponentially with the increase of hydrogen fraction in the fuel blends. The optimum hydrogen volumetric fraction in natural gas, is around 18% to get the compromise in both engine performance and emissions. HCNG reduces exhaust emissions and improves combustion characteristic. In this paper, the operating envelope, fuel economy, emissions, strategies to achieve stable combustion of HCNG engine, blending methods and world scenario are considered. Here in this paper the approach towards the blending of hydrogen with compressed natural gas in various proportions are shown and their performance and emission analysis has been done on a standard test bench and finally the outcome of the varoius analysis has been comapred with the performance and emission of compressed natural gas and also it has been discussed that how the blending phenomena of hydrogen gives better results than that of neat cng when the analysis of the fuels are compared with the emission norms provided by the government in their norms such as BS-2,BS-3,BS-4 etc. The paper presents an alternative approach in terms of fuel particularly in our country as we are largely depends upon the gulf countries for the import of crude oil as well as the fluctuation in the prices of the crude oil highly effects our economy, so there must be some alternative of this crude oil for the smooth operation of the vehicles running on the roads. As we all concerned about thecompressed natural gas which is being fuelled on various stations in some states of india e.g. delhi, u.p, haryana etc. The basic reason behind the use of gaseous fuel in an I.C engine is that there is no starting problem with the use of these gaeous fuel because they mix more more homogeneously with the air and finally makes a homogeneous mixture of air and the fuel. Also with incresing concern about energy shortage and environmental protection, research on reducing exhaust emission, reducing fuel consumption, reducing engine noise and increasingspecific outputs has become the major researching aspect in combustion and engine development. Alternative fuels such as CNG(Compressed Naturak Gas), H-CNG(Hydrogen enritched Compressed Natural Gas), LPG(Liquified Petroleum Gas), LNG(Liquified Natural Gas),PNG(Purified Naural Gas) Bio-Diesel, Hydrogen, Ethanol, Methanol, Di-Methyl Ether, Producer Gas, P-series have been tried world wide. Hydrogen as a future fuel for I.C engine has also been considered. But several obstacles have to overcome before commercialization of Hydrogen as an I.C engine fuel for automotive sector. Hydrogen and CNG blends may be considered as an automotive fuel without any major modification in the existing CNG engine and its infrastructure. In the present context a strategy has been worked out for converting the optimized CNG engine to run on HCNG. The testing has been carried out on a standard test bench firstly for neat CNG and furthur for 5% blends of hydrogen by volume with CNG and 18% blends of hydrogen by volume with CNG. It has been observed in the experimental work that H-CNG engines are much more superior to CNG engines from fuel economy, power output, emission complaince point of view. The power improvement of 3% to 4%, torque improvement of 3%, fuel consumption reduction of 4% is observed in H-CNG engine than the neat CNG engine. The H-CNG engine increses the H/C ratio of the fuel which drastically reduces the carbon based emission such as COH, CO2, THC, CH4 as well as NOX.***

***Keywords: Bio-Fuel, Emission Performance, CNG.***

## I. INTRODUCTION

Present scenario of today's global arena is the scarcity of the natural reserves in terms of fossil fuel. The rate of depletion of the fossil fuel is very high with the advancement of standard of living of the people. The requirement of energy thus increases in each and every sector. The sector whichhighly requires fossil fuel is automobile, here generally the liquid fuels are preferred for internal combustion engines but the rate at which petroleum products are being consumed there will again be a huge scarcity of petroleum as previously seen in the oil crisis in early 1970’s. Due to these reasons various alternatives for the internal combustion engines are look after and the research is being done in almost every part of the world. In this context natural gas has been found vary promising for its use in internal combustion engines and is in use in many parts of the world. In fact our country also uses compressed natural gas and are available in some states like union territory of Delhi as well as some adjoining states like Haryana, Uttar Pradesh etc. Almost every part of Delhi there is an availability of CNG at various fuelling stations. CNG has been found as one of the best fuel for its use in internal combustion engines as it mixes homogeneously with air, there is no starting problem, better thermal efficiency, least pollutant emission and various other features.Many other alternatives of petroleum products are LNG, PNG, Ethanol, Methanol, Di-methyl ether, LPG and H-CNG (hydrogen enritched compressed natural gas). So these alternative approaches are under investigation throughout the world for its productivity and reliability to be used in an internal combustion engine. This paper solely depends on the research work of blending process of hydrogen with compressed natural gas. Various blends of hydrogen is mixed with compressed natural gas to check its validity for its use in internal combustion engines working on bi-fuel mode. In this context 5% H-CNG (5% hydrogen and 95% CNG) and 18% H-CNG (18% hydrogen and 82% CNG) has been investigated and compared with neat CNG in terms of its performance and emission. The comparison is based on power output, torque, fuel consumption, exhaust pressure, exhaust temperature in terms of its performance and calculation of exhaust gases such as carbon monoxide, carbon Di-oxide, total hydrocarbon, oxides of nitrogen, methane has been revealed in terms of exhaust emission and later on compared with neat CNG in terms of all the above factors discussed above. As we all are concerned about CNG that it is far better that liquid fuel due to the following reasons; a) It mixes uniformly with air to provide a mixture which burns more completely than liquid fuels. b) There is no staring problem associated with the gaseous fuel c) Ignition delay is almost nil particularly physical delay d) It generally build up minimum carbon deposition e) Quantity of contaminating residue is very small. So these above discussed factors deviates a gaseous fuel basically CNG with a liquid fuel. The characteristics of CNG fuel will be discussed in subsequent chapter. Now let’s discuss about hydrogen, it is the most abundant gaseous element which can be harnessed as a fuel found in nature. Hydrogen is a fuel with clean burning and is renewable. The combustion and emission characteristics of hydrogen are superior to any other fuel competing it. It requires very low ignition energy and has a high heat of combustion. Hydrogen is the lightest element being about eight times lighter than methane (which forms the major part of CNG). Being lighter in weight defines its compactness for storage or transport. Due to the above discussed factors hydrogen has been regarded as the best gaseous candidate for natural gas due to its very fast burning velocity. It can be used for internal combustion engines in the following forms; a) Neat hydrogen b) Hydrogen supplementation (petrol+ hydrogen) c) Hydrogen + CNG (H-CNG) d) Duel fuelling (diesel + hydrogen) After the little approach to hydrogen and CNG, we must look after their mixture that what will be the result of these two blends when they are combined. Natural gas and hydrogen blends can be a viable alternative to fossil fuels because of the expected reduction of the total pollutant emissions. These blends offer a valid opportunity for dealing up with sustainable development in transportation sector, in view of the future more stringent emission limits for road vehicles as far as our country is concerned. H-CNG ( hydrogen enriched natural gas) as a new engine fuel not only owns the advantages of hydrogen and CNG but overcomes their disadvantages. Using H-CNG fuel can improve the fuel economy, decrease carbon monoxide, carbon Di-oxide, total hydrocarbon, oxides of nitrogen and ensures lean burning. The gaseous fuel are getting more positive response from researchers and end-users compared to past because of current unfolding developments. Therefore it is more economical and of environmental advantage to use gaseous fuel in an internal combustion engines that uses the bi-fuel concept. Most researchers have focused on the use of natural gas as an alternative fuel mainly due to its wide availability, clean burning and low cost compared to other gaseous fuels. In spite of the advantages of the natural gas, it has some disadvantages such as low burning velocity, poor lean burning capability. These problems lead to engine having high cyclic variations, longer combustion duration and lower power output. Hydrogen is the best additive candidate to natural gas due to its unique characteristics. Moreover, hydrogen has a wide flammability range which allows higher efficiency with leaner operation for reduced toxic emissions, low ignition delay and higher flame stability. The effect of adding hydrogen to natural gas can lead to shorter burning time, extended flammability and leaner limits of the mixture. Moreover hydrogen addition could broaden the range of EGR(Emission Gas Regulation) while maintaining low cyclic variations and low level of NOx emissions. H-CNG allows customers early hydrogen deployment with nearly commercial technology. It is being treated as the first step towards future hydrogen economy. Engines can be calibrated for lower NOX or greenhouse gas emissions. Any natural gas engine is compatible to run on H-CNG and can do so with minimum modifications. It also allows government and agencies to promote the use of hydrogen to greater number of people with less cost. H-CNG can help the hydrogen industry to develop volume and transportation solutions while reducing costs. H-CNG can take the advantage of existing investment in natural gas infrastructure and also has much higher volumetric energy storage density than pure hydrogen. However, as the hydrogen fraction increases above certain extent, abnormal combustion such as pre-ignition, knock, backfire occurs. Due to low quench distance and high burning velocity, the combustion chamber walls become hotter which causes more losses to cooling water. Therefore, the hydrogen being added should be optimized to compromise the gain and loss. With the increase of hydrogen earlier natural gas with hydrogen for use in an internal combustion engines is an effective method laminar burning velocity of 3.8 m/s for laminar burning velocity of 2.9 m/s for hydrogen verses a methane. This can improv the cycle by cycle variations to improve the burn velocity, with a addition, the lean operation limits extend and the mean brake torque decreases. This view has been the accelerant behind the renewed interest and recent progress in the research and development of H-CNG engines. As discussed caused by relatively poor lean burn capabilities of the natural gas engines. Hydrogen is characterised by a rapid combustion speed, a wider combustion limit and low ignition energy. These characteristics can reduce the exhaust emission of the fuel, especially the methane and carbon monoxide emissions. The fuel economy and thermal efficiency can also be increased by addition of hydrogen. H-CNG allows for initial use of hydrogen while taking advantage of current CNG infrastructure.

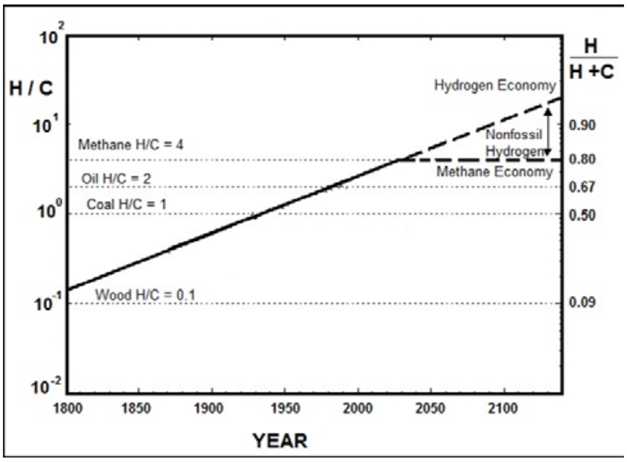


**Figure 1.1Decarbonisation: evolution of the ratios of Hydrogen to Carbon in the world primary fuel mix**

This allows for the hydrogen infrastructure to slowly become established until the production and efficiency demands can be met for hydrogen economy. The addition of hydrogen to natural gas also greatly reduces the carbon monoxide and carbon Di-oxide emissions. The H-CNG fuel can also help to avoid problems associated with evaporative emissions and cold start enrichment seen in gasoline engines and the high anti knock properties of CNG due to high activation energy helps resists self ignition.

## II. LITERATURE

*Hydrogen Blended Compressed Natural Gas*

Overview and characteristics:

H-CNG is a vehicle fuel which is a blend of hydrogen and compressed natural gas in varied proportions, typically 8-50% of hydrogen by volume. Mixture of 20% blending of hydrogen in compressed natural gas commonly known as Hythane. H-CNG can bridge the gap between traditional liquid fuels and hydrogen. By using H-CNG as a transition fuel and by taking the advantage of CNG prevailing substructure, there is a potential to initiate building hydrogen infrastructure at a minimum cost, even though hydrogen dedicated vehicles on a large scale. Besides the benefits a transition fuel, HCNG has its own specific advantage in terms of pernicious emission and if in addition the hydrogen is produced from renewable resources, HCNG could also contribute to reduce GHG emissions

The intensifying competition for environmentally welcoming vehicles can only be met by the use of ultra clean fuel like compressed natural gas (CNG) and hydrogen (H2). Lower carbon to hydrogen ratio of CNG makes it a cleaner fuel, due to this CNG is gaining popularity as an internal combustion engines fuels in transport sector.

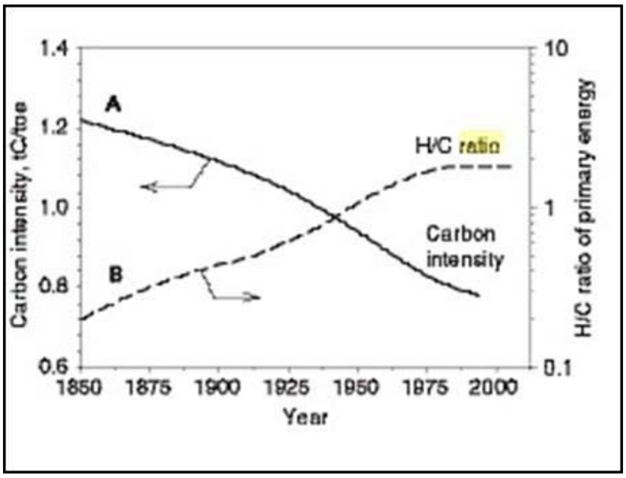


**Figure 1.2. Historical decarbonisation trends**

Hydrogen as a future fuel is supposed to be one of the most promising fuel for internal combustion engines because of the less carbon content and lesser carbon content simply means less emission. It can be deduced that pure hydrogen requires 4.52 times more hydrogen by volume at 25 MPa than pure methane for equal low heating values (LHV) energy storage which can be further rounded: that hydrogen requires 5 times more storage capacity than CNG, so blending of hydrogen should be limited so that there remains a leverage of storing the fuel.

So several obstacles have to be overcome before commercialisation of hydrogen as an IC engine fuel for transportation sector. The hydrogen enriched compressed natural gas fuel or simply HCNG fuel has the potential to lower emission and is considered to be the first step towards the hydrogen economy.

Many researchers have studied the blending of hydrogen with compressed natural gas on the basis of performances and emissions on dedicated or retrofitted SI and CI engines, whereas less work has been carried out in Bi-fuel SI engines thereby resulting in limited knowledge in this particular area. This survey contains major work done by highly reputed research scientists on their respective state of the art of experimental set up.

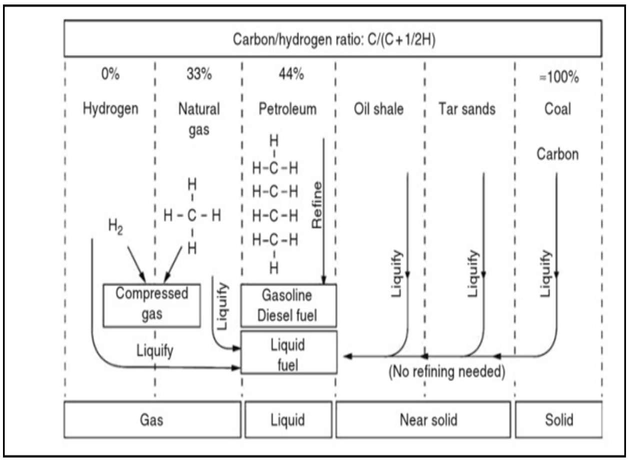


**Figure 1.3. Carbon Hydrogen ratio**

**Table1.1 Table 2.1.4.Comparision of properties of Hydrogen, HCNG5, CNG and Gasoline**

| Properties | Units | H2 | HCNG 5 | CH4 | Gasoline |
|---|---|---|---|---|---|
| Limits of flammability in air, | *vol.%* | Apr-75 | **May-35** | May-15 | 1.0 -7.6 |
| Stoichiometric composition in air, | *vol.%* | 29.53 | **22.8** | 9.48 | 1.76 |
| Minimum energy for ignition in air, | *mJ* | 0.02 | **0.21** | 0.29 | 0.24 |
| Auto ignition temperature, | *K* | 858 | **825** | 813 | 501-744 |
| Flame temperature in air | *K* | 2318 | **2210** | 2148 | 2470 |
| Flame velocity in NTP[1] air, | *m/s* | 3.25 | **1.1** | 0.45 | 0.37-0.43 |
| Quenching distance in NTP3 air, | *Mm* | 0.64 | **1.52** | 2.03 | 2 |
| Normalized flame emissivity | 1 | **1.5** | 1.7 | 1.7 | 1.7 |

**Karim et al[2]** proposed in his theory the addition of hydrogen on methane combustion characteristics at different spark timing. The theoretical outcome displays that the addition of hydrogen with natural gas could decrease the ignition delay and combustion duration at the same equivalence ratio. It specifies that the addition of hydrogen could upsurge the flame propagation velocity thus stabilising the ignition progression particularly the lean combustion process.

**Ilbas et al [3]**experimentally calculated the laminar burning velocities of hydrogen-air and hydrogen-methane-air. They concluded that progressing the hydrogen percentage in hydrogen-methane mixture causes an increase in subsequent burning velocity and produced broadening of the flammability limit

**RejiMathai et al[5]** state that brake fuel consumption is lesser in HCNG compared to CNG due to high calorific value and improved combustion efficiency. At 18% HCNG the flame speed stabilizes and accelerates the combustion process thus enabling the degree of Constant Volume Combustion (CVC). At the same H-CNG ratio the CO and HC emission drastically decreases but NOx emission increases as compared to compressed natural gas (CNG).

**M Ayoub et al [6]**explains that at excess air ratio the CO emission decreases and if hydrogen percentage increases then we see a progressive decrease in NOx emission.

## III. EXPERIMENTAL LAYOUT

A four cylinder light duty gasoline engine is used for experimental studies. The specification of the engine is tabulated below. The engine has retro fittings for CNG injection and rest everything (compression ratio, piston, cylinders etc) is in company specs to run on gasoline.

**Figure 1.5Outer view of the engine test bench and controlling devices**

**Figure 1.4. Engine Test Bench**

An automatic test bench control and data acquisition system is used for conducting the test and record data. The systematic diagram of engine test bench has been shown in figure 3.1. AVL equipmentshas been used for fuel conditioning and other engine parameters and engine exhaust measurement are done using HORIBA exhaust gas analyser.

**Table 3.1 Engine Specifications Parameter Description**

| Parameter | Description |
|---|---|
| Engine Type | 4-cylinder, 4 Stroke, Liquid Cooled gasoline engine |
| Brake Horse Power | 73bhp@6000rpm |
| Torque | 101Nm@3000rpm |
| Power Output | 54.4kW |
| Bore | 71.03mm |
| Stroke | 75.44mm |
| Displacement | 1196cc |
| Compression Ratio | 9.9: |

Performance , emissions and fuel ingestion are base expansion targets causing dedicated demands on advance results for automobile applying combustion engines. Irrespective of which testing situations the development actions need to be rein forced with commanding and smart apparatus and clarifications that the area also exciting the today’s anticipated superiority in efficiency. So at the test arena: engine test chamber is mounted with state of art of the technology which badges them with honour of highest rated efficiency figure, which are reserved by the following equipment from world’s leading companies like AVL and HORIBA.

Systematic Diagram of Engine Test Bench

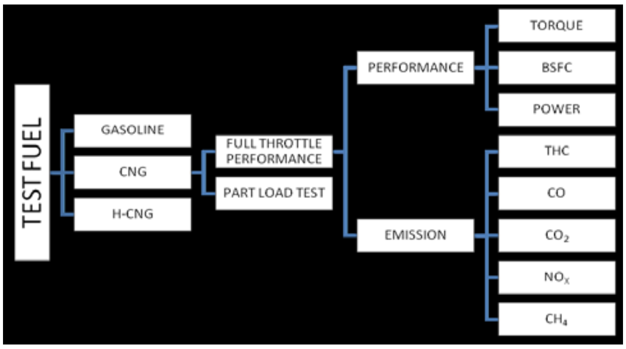


**Figure1.6.Test bench Layout**

Bi-Fuel Engine Parameters

| PARAMETER | DESCRIPTION |
|---|---|
| Engine type | 4 cylinder,4 stroke liquid gasoline cooled engine |
| Brake horse power | 73 bhp @ 6000 rpm |
| Torque | 101 Nm @ 3000 rpm |
| Power output | 54.4 kW |
| Bore | 71.03 mm |
| Stroke | 75.44mm |
| Displacement | 1196 cc |
| Compression ratio | 9.9:1 |

Horiba Mexa Exhaust Gas Analyser

Figure1.7. Horiba Mexa Exhaust Analyser

## IV. CONCLUSION AND RESULT

*Full Throttle Performace Test*

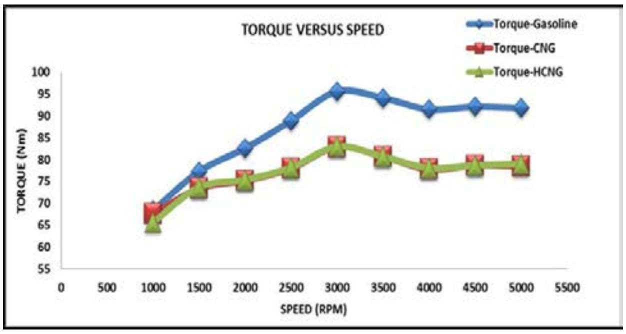


**Figure1.8.Torque Vs Speed in Full Throttle Performance Test**

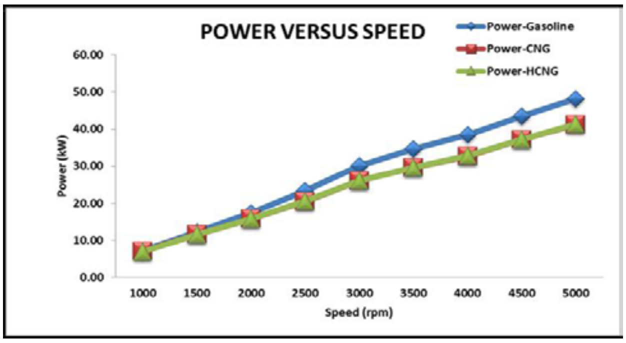


**Figure 1.9. Power Vs Speed in Full Throttle Performance Test**

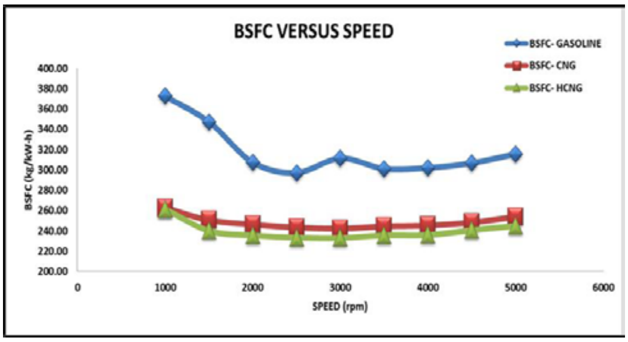


**Figure 1.10. Brake Specific Fuel Consumption Vs Speed in Full Throttle Performance Test**

## V. EMISSION RESULTS

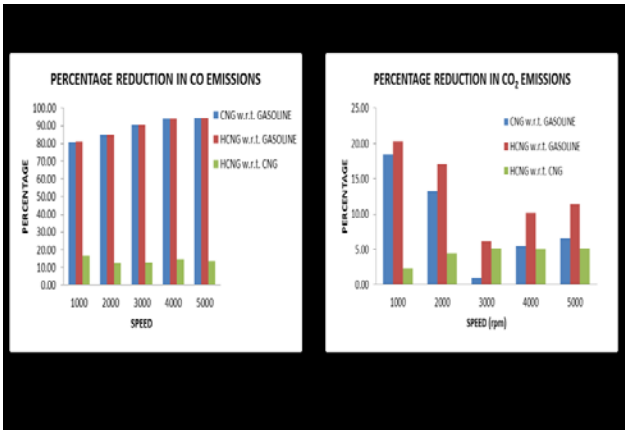


**Figure 1.11. a) Emission results for CO Vs Speed, b) Emissions for CO2 Vs Speed at full Throttle Performance Test**

PART LOAD PERFORMANCE TEST:

PART LOAD EMISSION RESULT @ 25% LOAD

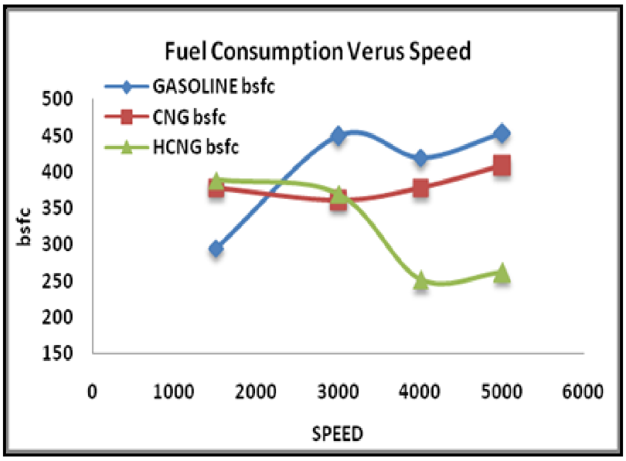


**Figure 1.12: Fuel Consumption curves versus Speed at 25% load**

PART LOAD PERFORMANCE TEST AT 50 % LOAD

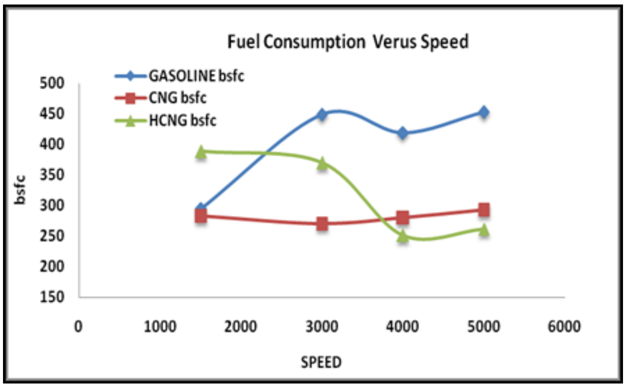


**Figure 1.13 Fuel consumptions curves versus speed at 50 % load**

From the above discussions we came to the conclusion that there is no doubt for the use of hydrogen blended compressed natural gas in an internal combustion engines working on either Bi-fuel mode or dual fuel mode. From the result section we can easily notice that H-CNG fuel is one of the prominent option for an I C Engine. Also the behaviour shown by H-CNG fuel in terms of performance and emissions are remarkable. There is a huge amount of declination in the NOx emissions which is of a great concern in today's automobile market and a sort of relief for the researchers as they are working very curiously for decreasing the emissions coming out of the exhaust port and why not as these emissions are very dangerous for human as well as environment, lot of serious damages are being done by these emissions as they contribute to global warming and very serious diseases like cancer, throat problem etc.

In general we can say that this fuel has a promising future if and only if they are produced on a large scale as well as for establishing this particular fuel as common for public we need a far sight plan and huge amount of piping network which should be established for implementation of this fuel.

## REFFERENCES

[1] U. S. E. I. Administration, "Index Mundi," EIA, [Online]. Available: http://www.indexmundi.com/energy.aspx?region=xx&product=total-primaryenergy&graph=production+consumption. [Accessed January 2015].

[2] The Automotive Research Association of India, "Indian Emission Regulations," © Head Legal - ARAI, Pune, Pune, 2011. [3]D. Williams and G. Jones, Liquid Fuels. [4]Shaha, A. K. Combustion Engineering and Fuel Technology, Oxford & IBH Publishing Company.

[5] U.S. Department of Energy,," Office of Energy Efficiency and Renewable Energy, Alternative Fuels Data Center, [Online]. Available: http://www.afdc.energy.gov/afdc/fuels/properties.html.