Comparative performance of a SI engine retrofitted for CNG fuel application.

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ABSTRACT

Rising household incomes, improving Indian economy and drastic population growth are some of the major contributing factors for high power requirement in India. To meet the power requirement in urban and rural area, generators working on diesel, gasoline and kerosene have evolved in the past years. With many advantages generators do come with serious concerns of environmental pollution. Portable Gasoline gensets emit harmful HC and CO emissions. Compressed natural gas (CNG) due to its easy availability and excellent fuel characteristics has gained momentum as an alternative fuel to gasoline and diesel in automobile sector and is a viable solution for reducing the emissions. This paper studies the effect of compressed natural gas on the performance of a portable genset. Performance test at varying load with gasoline and compressed natural gas as fuel has been done to study the emission and performance characteristics of the engine. Endurance test of 60 Hrs duration has been done to assess the effect of compressed natural gas on engine life by evaluating the chemical-physical properties of engine oil used during the test. The tests have clearly shown that there is substantial reduction in exhaust emissions using CNG fuel, improvement in BSFC and further optimization of the fuel intake system can lead to better NOx control.

INTRODUCTION

Among developing nations, China and India have the fastest growing economies. By 2030, China and India are projected to use 25% of the world's energy budget [1]. Such economic growth would call for increased demand for energy and ensuring access to clean, convenient and reliable energy for all to address human development. To deliver a sustained growth of 8% through 2031, India would need to grow its primary energy supply by 3 to 4 times and electricity supply by 5 to 7 times of today's consumption [2].

The impact of the widening shortfall in power generation is being felt in rural areas as well as urban areas and therefore requires immediate attention.

Generator market has grown as a standard and well accepted solution for reducing the power deficit in urban and rural households. Apart from the power crisis, other contributing factors for the growth of generator market are robust economic growth, rise in household incomes, and the real-estate boom.[4]. The market size for generators is expected to grow over Rs 10 billion every year. New technology too holds great promise for this segment. 'Lean burn gas gensets', capable of fuel management according to load using cleaner natural gas, and photovoltaic systems coupled with smaller fossil fuel based generators as backup will be the wave of the future.

Compressed natural gas is one of the most promising fuel alternatives for the future and demand for CNG is projected to increase in the next decade. Compressed natural gas typically consists of over 80% of methane (CH_4), and some other hydrocarbons (mainly ethane and propane), and other gases such as nitrogen, helium, carbon dioxide, hydrogen sulfide, and water vapor as impurities [3]. A relatively low flame speed and low temperature combustion of CNG engines help to mitigate NOx emissions when operating with high compression ratio or when the engine is supercharged [3] under optimized fuel injection conditions. The present studies focus on the conversion of a gasoline genset to use CNG fuels and the related findings. The intake manifold was modified for introducing CNG.

EXPERIMENTAL SECTION

TEST SET-UP

The test set up has been designed as per the recommendation given in SAE J1088 test procedure for measuring exhaust gas emissions from small utility engines.

Engine performance and endurance test was conducted on a gasoline operated genset engine. The detailed specification of the engine is given in Table-1

Table-1: Test Engine Specification

	Description	Values
1.	Rating:	12.2 hp at 3600 rpm
2.	Bore , mm	58
3.	Stroke, mm	68
4.	Displacement, cc	369
5.	No. of Cylinders	2
6.	Compression ratio	8.5
7.	Generator Output	5 kW
8.	Coolant	Water

The engine was converted by installing a CNG kit to the inlet manifold with a provision to vary the CNG flow rate to control the Air-fuel ratio (AFR). This offered the advantage of maintaining AFR close to 1.

Exhaust temperature, coolant inlet and out let temperatures, oil sump temperature were measured. Oil pressure was also monitored.

Exhaust emissions were measured for CO, HC and NOx. Lambda and CO_2 were also monitored using portable emission analyzer.

TEST OIL

SAE 10W30 oil meeting API SL specification was used as the lubricant for all the tests

Table-2 : Oil Specification

K.V@100°C , cst	11.03
K.V@40°C, cst	77.33
VI	144
TBN, mg-KOH/g	8.2
CCS @-25°C, cP	5642
Flash Point , °C	224

TEST FUEL

Gasoline (Euro III) and compressed natural gas were used in the performance and endurance test.

TEST PROCEDURE

Performance test was conducted on the genset as per ISO 8178 emission test cycle (D1 cycle) for small capacity gasoline engine of power less than 19 kW using gasoline and compressed natural gas as fuels. The cycle consists of operating the engine at three different conditions of torque ie 100%, 75% and 50% and measuring emission parameters in each condition.

Also endurance tests were conducted at constant load of 3.5 kW for sixty hour duration using gasoline and CNG fuels to evaluate long duration effect of the fuel on the engine life. Oil samples were drawn at regular intervals of 15 hours to evaluate chemical and physical properties of the engine oil to study the effect of fuel on the engine oil.

RESULTS AND DISCUSSION

The comparative engine performance and emission characteristics of the engine using gasoline and CNG fuels and the endurance test results are presented.

ENGINE PERFORMANCE

Fig-1 and 2 show the comparative performance of brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) using both the fuels. The BSFC of engine with compressed natural gas is slightly better than that of gasoline and so is the brake thermal efficiency which may be due to higher calorific value of compressed natural gas. But at higher loads the BSFC values are almost similar. It is observed that for both the fuels, brake thermal efficiency is increasing with increase in load whereas BSFC is decreasing with the increasing load. Such trend of variation in brake thermal efficiency and BSFC is normally seen in a carbureted engine[5]. The improvement in BSFC for CNG is lesser as the AFR was maintained close to 1 in all the three torque stages. At higher load gasoline gives better efficiency, may be due to poor volumetric efficiency of CNG. Better performance using CNG has been cited by researchers when gasoline engines are retrofitted for CNG operation [5].

EMISSION CHARACTERISTICS

Fig 3 –5 shows the effect of varying load on the emissions of the engine with gasoline and compressed natural gas. With CNG the reduction in CO and HC emissions are approx. 55-80% and 27- 56% respectively whereas at higher load, increase in NOx emissions with CNG is around 45%.This implies that carbon monoxide and HC emissions of the engine with CNG is lower than gasoline and is mainly due to lower carbon content of CNG than gasoline. On the other hand NOx emissions with CNG is higher than gasoline at higher load. This is mainly due to the fact that at higher load the gasoline fuel operates at lower AFR (ie richer mixture) whereas CNG operates at leaner AFR leading to higher exhaust temperature and higher NOx. There is a need to optimize the engine to operate in leaner regime to reduce NOx emissions. The lowering of CO and HC emission and increase in NOx emission trends have been reported by researchers [5,6]. Employing EGR, port injection can further lower the exhaust emissions.

GREEN HOUSE GAS EMISSIONS

Carbon dioxide is considered as one of the major green house gas and Fig-6 clearly implies that there is at least 20 - 25 % reduction in CO_2 emissions using CNG. This is due to higher hydrogen to carbon ratio of CNG. The emission test results amply advocate the use of CNG for such applications.

ENGINE ENDURANCE TEST- ENGINE OIL PERFORMANCE

Endurance tests has been used extensively for assessing the impact of fuels & lubricants on engine components [7,8]. The endurance tests of 60 hours duration was conducted using CNG & gasoline fuels. Fig 7 shows the variation in the concentration of iron in the used engine oil with respect to test hours. It is observed that the iron concentration in engine oil with CNG as fuel is higher than that of gasoline. The percentage variation is in the range of 60 – 150 %. It is evident that compressed natural gas causes higher wear in the engine than gasoline when operated for long hours. This may be also due to the fact that the lubricant used was optimized for a gasoline engine implying the requirement of dedicated lubricants for gas engine applications.

Fig 8 shows the variations in Kinematic Viscosity when the engine is operated with CNG and gasoline fuels. The variation of kinematic viscosity for gasoline and CNG is in same range. Hence it can be concluded that the engine oil is able to resist the oxidation with CNG fuel.

The performance of the engine ie BSFC and emission characteristics during the endurance test period using both the fuels had not deteriorated showing that the fuel has no adverse effect on the engine components.

CONCLUSIONS

- The comparative engine performance using both the fuels and the endurance tests have indicated that the use of CNG has no adverse effect on the engine performance.
- Better BSFC of the engine using CNG fuel while delivering the same power, is an impetus to utilize the fuel on a wider scale.
- The exhaust emissions of CO and HC have shown substantial reduction whereas NOx shows an increasing trend at higher loads while using CNG fuel.
- To reduce the NOx emissions at higher load, there is a need to optimize the CNG fuel injection or EGR has to be employed.
- There is a need to use dedicated lubricants for gas engine applications to derive best performance. This will not only enhance engine life (by reducing wear) but also will have longer drain periods.

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REFERENCES

1. U.S. Energy Information Administration, International Energy Outlook, 2008
2. “Integrated Energy Policy”, Planning Commission of India, Dec 2005.
3. Nils-Olof Nylund, VTT Energy, Finland, Alex Lawson, GFI Control Systems, Inc., Canada, “EXHAUST EMISSIONS FROM NATURAL GAS VEHICLES”, Issues related to engine performance, exhaust emissions and environmental impacts, A report prepared for the IANGV Technical Committee.
4. http://www.constructionupdate.com/products/constructionworld/2007/cw_june-07/013.html
5. Aslam M.U., Masjuki H.H., Kalam M.A., Abdesselam H., Mahlia T.M.I., Amalina M.A. “An experimental investigation of CNG as an alternative fuel for a retrofitted gasoline vehicle” Fuels 85 (2006) 717– 724.
6. Unich A., BataR.M. and LyonsD.W. “ Natural Gas: A promising fuel for IC Engines” SAE paper no 93029.
7. Chausalkar A. et al “Engine Endurance Test: Effect Of Bio Diesel On A Euro II Diesel Engine and Lubricant.” SAE 2008-28-0122.
8. Mathai R. et al, “Performance Evaluation of an API CH-4/ACEA E-5 Diesel Engine Oil in Endurance Test: Lab Study to Rationalize Drain Period” SAE 2006-28-0019.

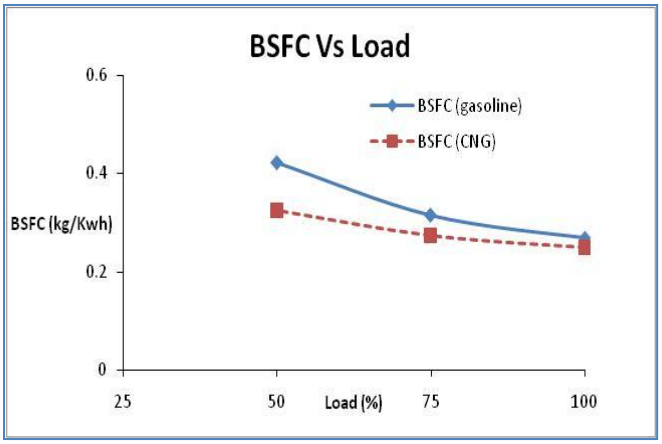

Fig 1: Brake specific fuel consumption Vs load (%)

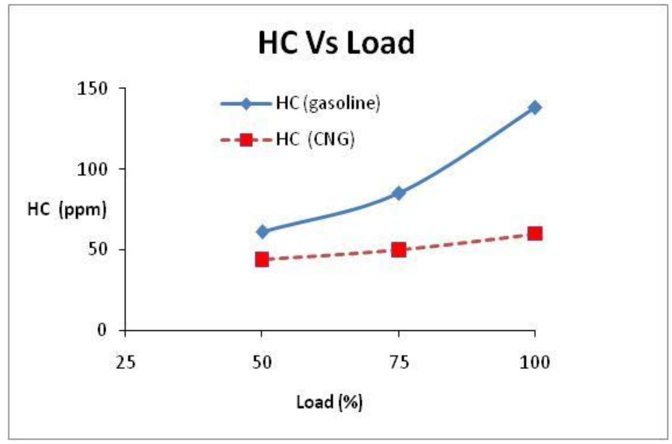

Fig 4: Variation of HC emissions vs. load (%)

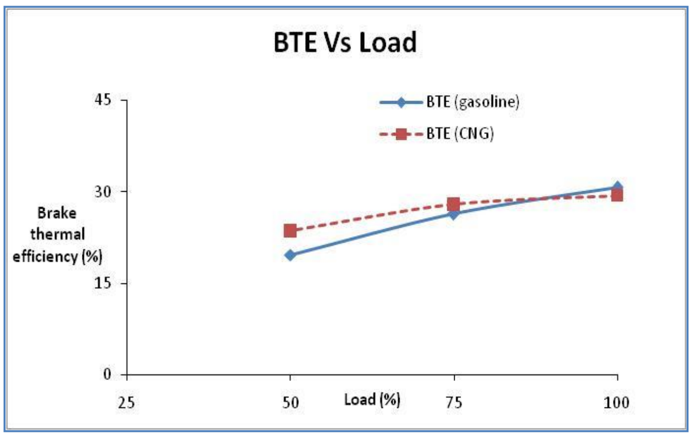

Fig 2: Brake thermal efficiency Vs load (%)

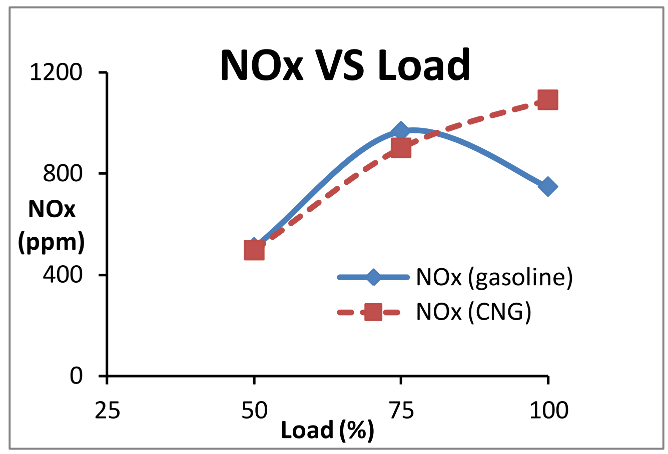

Fig 5: Variation of NOx Vs. load (%)

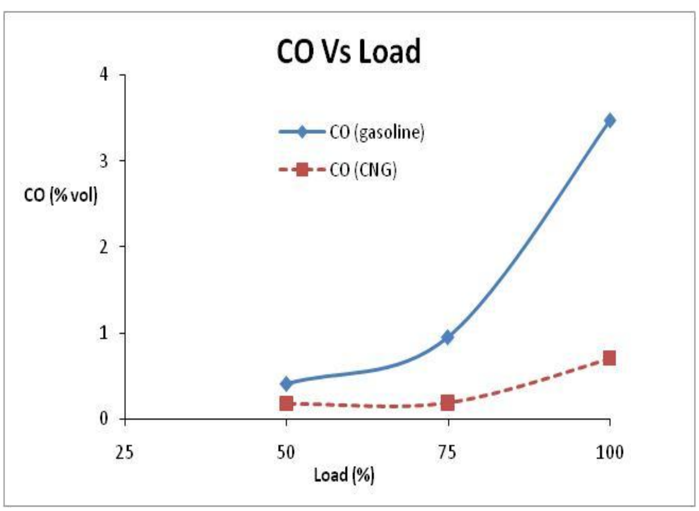

Fig 3: Variation of CO emissions Vs. load (%)

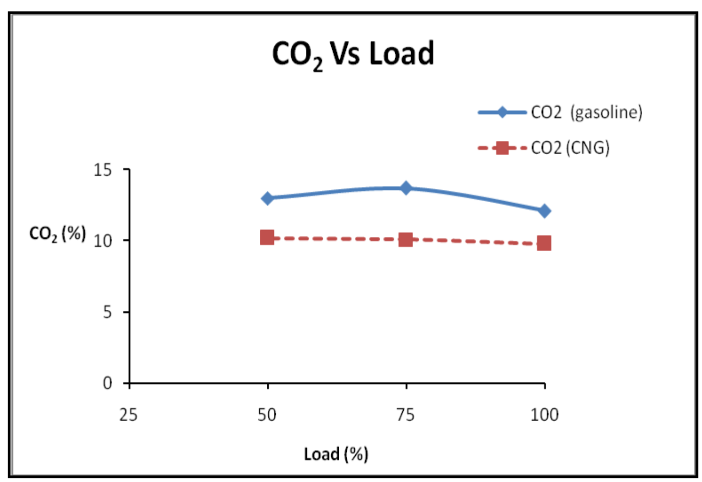

Fig 6: Variation of Carbon dioxide with load (%)

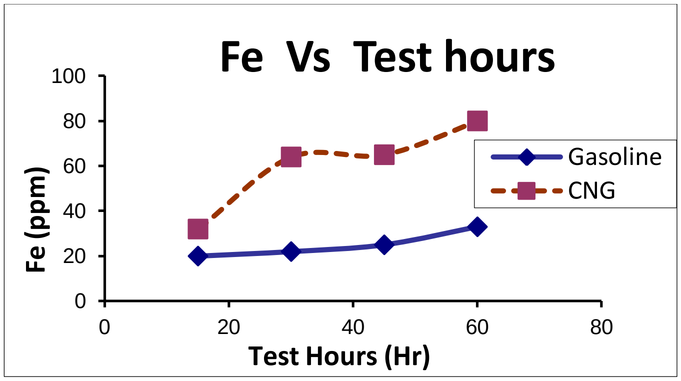

Fig 7: Variation of Fe (ppm) with Test hours

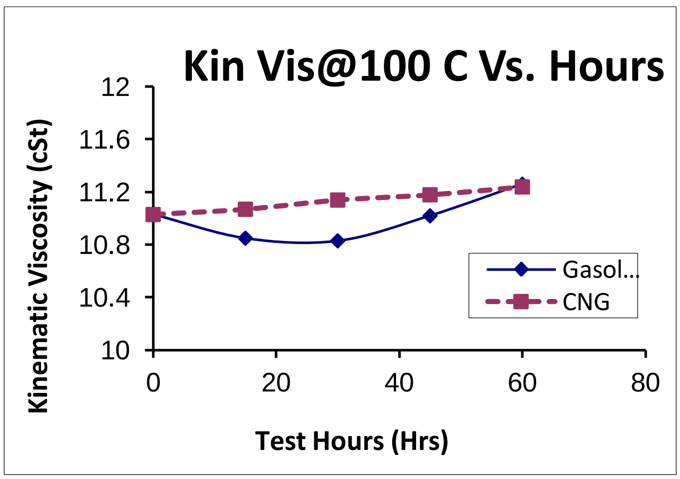

Fig 8: Variation of Kinematic viscosity with Test hours

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ABBREVIATIONS

AFR – Air Fuel ratio
BSFC – Brake Specific Fuel Consumption
BTE- Brake Thermal Efficiency
CNG – Compressed Natural Gas
EGR – Exhaust Gas Recirculation
Fe – Iron
HC- Hydrocarbon emissions
TBN – Total Base Number
VI – Viscosity Index