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Performance effects of increase in Hydrogen percentage by volume on CNG sequential Injection 3 cylinder S.I Engine.

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Abstract:

Now days the Global warming has become the important issue. Nation is also facing the fuel crises due to increase in Automobiles sector. The blends of Hydrogen and CNG have the potential to satisfy Euro V norms with margin. Experimentation on 3 cylinder water cooled SI engine with eddy current Dynamometer, modified to CNG sequential Gas Injection system with varying percentage of hydrogen by volume shown the reduction in emission and increase in power output.

Introduction :

Due to high thermal efficiency and power density IC engines are widely used as transportation and stationary power source Kyoto protocol calls for a reduction in greenhouse gas emission between 2008 to 2012 to the levels that are 5.2 % below 1990 level in 38 industrialized countries. IC engines exhaust emissions, due to stringent emission norms caused engine manufacturer to examine the potential of alternative fuels. CO2 reduction in mobility sector is a major challenge for next decade. 30 billion tons of CO2 is added to atmosphere every year by all the nation. Non Methane Hydro Carbon (NMHC) is a green house gas with global warming factor. After treatment devices are expensive and have imposed constraint on E-IV .Gaseous fuel mix uniformly with air which burns precisely during combustion than liquid fuels. It has minimum carbon deposition & negligible physical delay.

CNG due to its potential for low PM and carbon based emissions such as HC, CO, PM, etc is looked as best alternative fuel. It has cleaner combustion characteristic and plentiful reserves. Current gasoline engine can be modified due to (stiochometric mixture, closed looped fuel control and exhaust catalyst) for CNG. More research & development work is going on worldwide to investigate various aspects of CNG in SI engines. CNG slow burning flame velocity & poor combustion stability & hydrogen high burning flame velocity (7 times of CNG) combines the advantage of HCNG to form shorter combustion duration, greater constant volume degree as well as improved ITE. CNG has simple chemical structure & wide flammability range and absence of fuel evaporation. Its high octane number (>130) give the engine high anti-knocking capability and allows it to operate at even high compression Ratio. CNG poor lean burn ability leading to incomplete combustion, High misfire ratio and large cycle by cycle variation at Lean Mixture combustion can be improved by adding Hydrogen.

Hydrogen able to burn at ultra lean at an equivalence ratio of 0.1, comparing methane Phi=0.53 and Gasoline Phi=0.7.Hydrogen quenching distance of 0.064 cm is approx. !/3 that of methane or gasoline. HCNG reduces exhaust emissions and improves combustion characteristic. CNG H/C ratio is approx. in the range of 3.7 to 4.0. With modern technology CO2 emission reduction of 30 % for small car is possible. New technology use increase in CR, with specially developed turbo-charging strategy and EGR to reduce engine out NOx emission. CNG reduces PM by 90 % and NOx by 50 % compare to diesel engine. As CNG is a dry fuel there is more wear & tear of exhaust & inlet valve & engine parts as compared to conventional fuel gasoline. With CNG 42.5 % reduction in CO compared as gasoline and THC have increased with CNG with marginal decrease in NOx .It is observed that Gas Injection system has more potential compared to gas Mixture system and 10 % improvement at higher speed is observed.

Literature Review: Natural gas is the mixture of methane (99% of total volume) non methane hydrocarbons such as ethane, propane, and butane and in some cases trace of higher hydro carbons as well as inert gases like nitrogen, helium, carbon dioxide hydrogen sulphide, and sometimes water. NG reserves are 5288.5triltion cubic feet which is larger than crude oil. Petroleum one 1000 billion barrel going to consumed in about 40 years.

Shrestha and Karim investigated proportions of 100/0, 90/10, 80/20, 70/30, and 10/90, CH4/H_2, percentage in different compression rates by varying equivalence ratio. They stated that the addition of some hydrogen to methane in SI engine enhanced the performance, particularly when operating on relatively low equivalence ratio mixtures. The optimum concentration of H_2 in the fuel mixture for producing power gain and avoiding knock appears to be about 20-25% by volume over the range of conditions considered.

Bauer and Forest studied the effect of H_2 addition to the performance of methane fueled vehicles. They used one cylinder research engine at compression ratio 8.5:1. They analyzed brake power, ITE, spark degree (BTDC), $BSCO_2$, BSCO, BSHC, BSNO, in 100/0,80/20,60/40,40/60 CH_4/H_2 changing equivalence ratio, load and speed (700 and 900 RPM). They concluded that when compared to pure methane hydrogen addition up to 60% volume was shown to lower the partial burn limit from an equivalent ratio of 0.58-0.34. There was a corresponding increase in brake power up to 80% (at Ø=1.0) and decreases in BSfc up to 14% (from Ø =0.58 to 1.0). For pollutant production, hydrogen addition up to 60% volume resulted in a decrease in $BSCO_2$ up to 26% (from Ø =0.58 to1.0), a decrease in BSCO up to 40% (for Ø >0.95), a decrease in BSHC up to 60% (from Ø =0.58 to 1.0) and a increase in peak BSNO at Ø =0.83 of approximate 30% (for volumetric fraction =40%)

Karim investigated hydrogen as SI engine fuel. He concluded that there were excellent prospects to achieve very satisfactory SI engine operation with hydrogen as the fuel and most of the subject whether hydrogen could be obtained abundantly and economically remained yet to be un used satisfactory.

T. Thurnheer and P. Dimopoulos carried out performance of gasoline, methane and HCNG blends of 5, 10 & 15% H_2 by volume on 2 liter NA bi-fuel engine with Port fuel injection. At 2000RPM and 2bar BMEP and stiochometric combustion heat release analysis and a loss analysis were performed. It was observed that 15%H_2, optimized spark timing retardation by approximately 4.5^{0}CA compared to CNG. Adding hydrogen to methane lead to decreased real combustion losses while the wall heat losses increase. Compared to methane gasoline has smaller real combustion losses and slightly smaller wall heat losses. However losses due to gas exchanged are larger. Fuel conversion efficiency increased by blending methane with hydrogen. It states that care has to be taken when comparing fuel conversion efficiency among the different fuel as relative error in fuel conversion efficiency for the gasses fuel is 0.2% at most, where it is about, 1% for gasoline.

Table 1: Engine Specifications:

Product	Engine test setup 3 cylinder, 4 stroke, Petrol (Computerized)
Engine Make	3 cylinder, 4 Stroke, Petrol(MPFI), water cooled, Power 27.6KW at 5000rpm, Torque 59Nm at 2500rpm, Stroke 72mm, Bore 66.5mm, 796cc, CR 9.2
Dynamometer	Type eddy current, water cooled, with loading unit
Piezo sensor	Range 5000 PSI, with low noise cable
CNG	Sequential Port Injection ECU integrated to SI Engine ECU
Hydrogen	Online Hydrogen Blending with 2 stage Pressure Regulator, Flame trap and Flame arrestor.

Experimental setup:

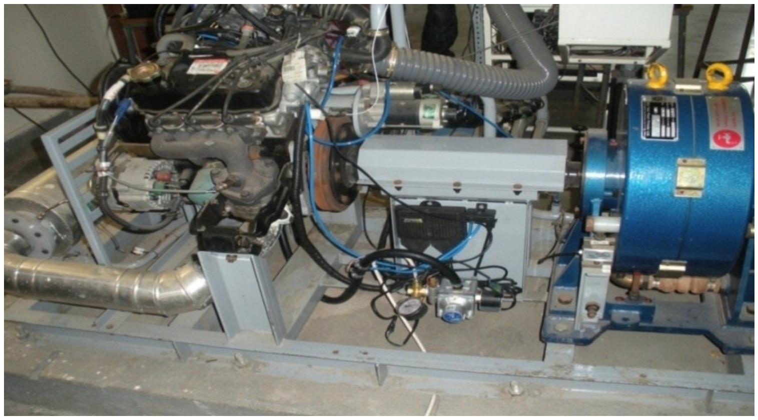


Table 2: Properties of Gasoline and CNG fuel:

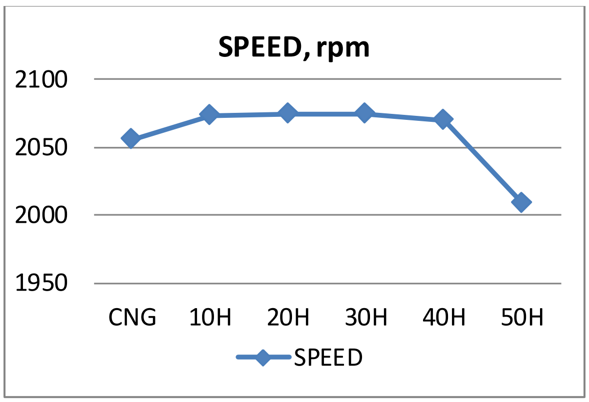
Sr No	Property	Units	Methane	Gasoline
1.	Limits of flammability in air	Vol %	5.3-15	1-7.6
2.	Laminar Burning velocity in air	cm/s	37-43	37-43
3.	Minimum Ignition energy in air	MJ	0.29	0.24
4.	Auto Ignition temp.	K	813	501-744
5.	Quenching gap in air	mm	2.03	2
6.	Diffusion coeff. in air	cm^2/s	0.16	0.05
7.	Density (Gas)	Kg/m^3	0.7174	5.11
8.	Flame temp. in air at $\lambda=1$	K	2148	2470
9.	Lowest Heating value	MJ/Kg	53	44
10.	Research Octane Number		>120	90-100
11.	Normal boiling Point	K	111.6	310-478
12.	Equivalence Ratio Ignition Lower Limit in NTP air	ϕ	0.53	0.70
13.	Volumetric LHV at NTP	KJ/m^3	32573	195800
14.	Stiochometric A:F ratio	Kg/Kg	17.19	15.08

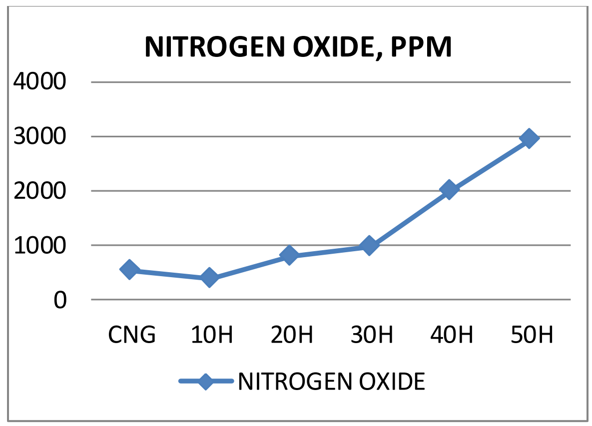
15.	Volumetric Fraction of Fuel in air Ø=1 at NTP		0.095	0.018
16.	% thermal Energy radiated from flame to surrounding		23-33	30-42
17.	Density (Liquid)	Kg/lit	0.42	0.73
18.	Molar Carbon to hydrogen ratio		0.25	0.44
19.	Quenching distance in NTP air	(cm)	0.203	0.2
20.	Higher Heating value	MJ/Kg	52.68	48.29
21.	Higher Heating value	MJ/m^3	37.71	233.29
22.	Lower Heating value	MJ/m^3	33.95	216.38
23.	Combustion Energy per kg of stoich. mixture	MJ	2.56	2.79
24.	Kinematic Viscosity at 300 K	mm^2/s	17.2	1.18
25.	Diffusion coeff. into air at NTP	cm^2/s	0.189	0.05
26.	Energy of stiochometric mixture	MJ/m^3	3.5	3.9
27.	Thermal Conductivity at 300 K	mW/mk	34	11.2

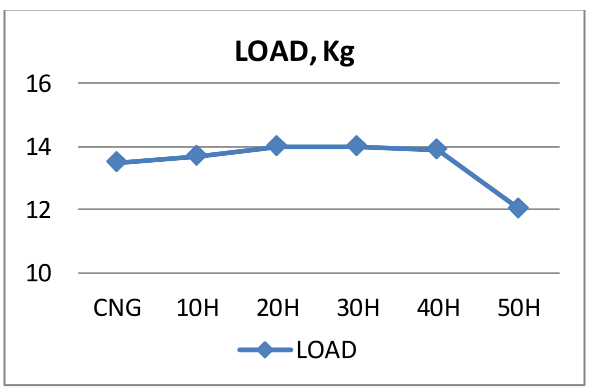
Experimental results:

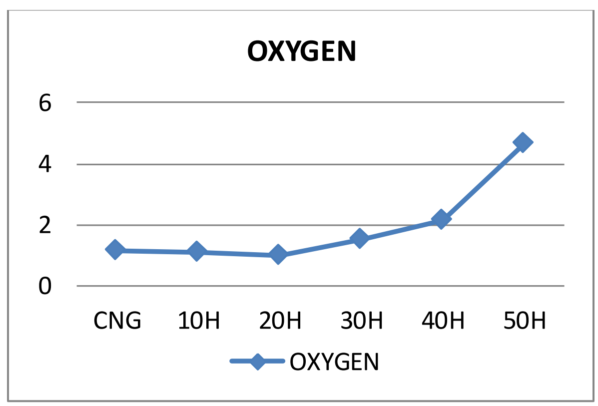
The experimentation was performed to check the durability of the SI engine and engine parts with increase in hydrogen percentage by volume. During the trial initially the engine was brought to the part load at the speed of 2000 rpm. Later the engine was kept at same condition and only the hydrogen supply was varied from 10 litre per minute to 50 litre per minute.
With increase in the percentage of hydrogen there was reduction in speed after 30 litre per minute of hydrogen by volume. Also there was reduction in the supply of CNG due to sequential gas injection. Approximately the fuel blend consumption was 70 litre per minute. During the trial the CNG consumption was reduced by 50% at 50 litre per minute of Hydrogen. Air consumption was also reduced by 12- 15 % due to lower density of hydrogen. During the trial exhaust temperature was increased drastically. It was above 1700^o C due higher calorific value of hydrogen. It get increased with increase in hydrogen percentage. The injection pressure of CNG was 1.8 bar which was controlled by Pressure regulator and hydrogen pressure was also 1.8 bar controlled by two stage regulator. The injection of HCNG blend was through Gas injector

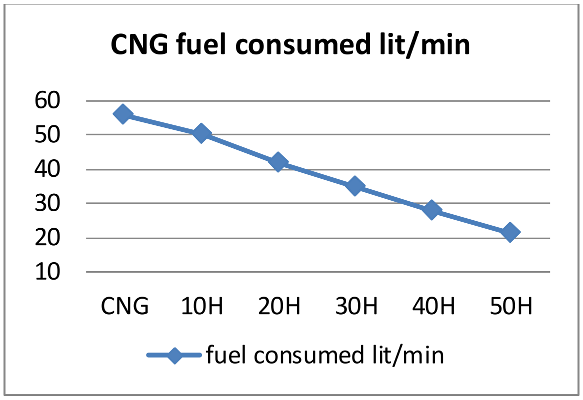
provided near inlet port. It was observed during trial that CNG after pressure reduction from 200 bar to 1.8 bar there was reduction in temperature of CNG (below 2^o C). Due to reduced temperature of CNG erratic combustion was observed increasing NMHC percentage at idle condition. Hence to reduce the NMHC emission heating arrangement was provided. The hot water coming out from the engine was circulated through CNG regulator to increase the temperature of CNG. There was increase in cylinder pressure with increase in HCNG blend

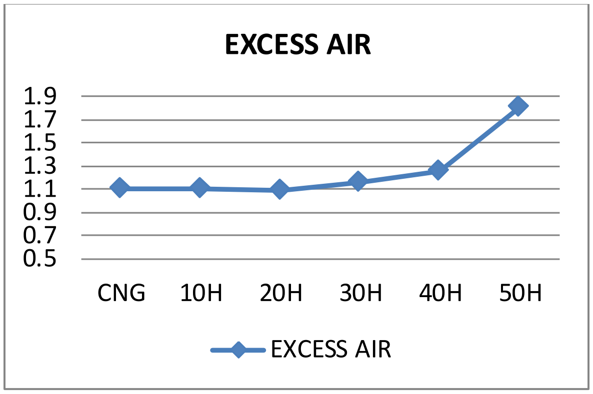


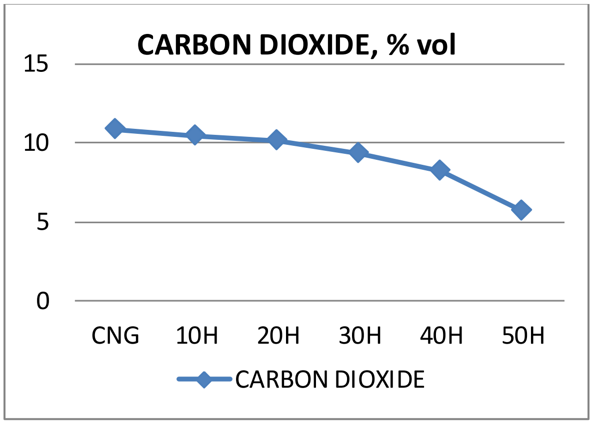


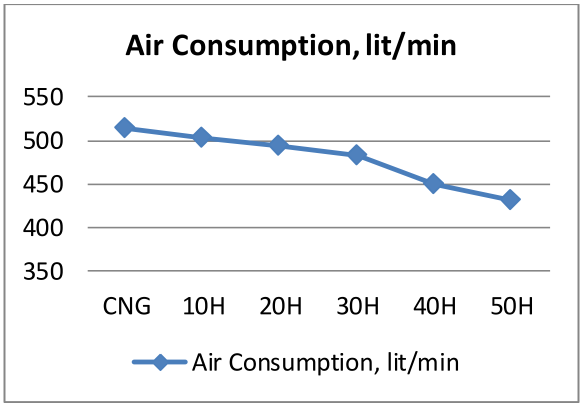












Conclusion:

1. This study has demonstrated that sequential type CNG conversion kit in gasoline engine has a potential for improved fuel economy and higher fuel conversion efficiency with significantly lower exhaust emissions.
2. On average, CNG operation results in 22% less BSFC.
3. CNG produces less 8-16% of brake torque, brake power and BMEP compared to gasoline fuel at WOT condition due to reduced volumetric efficiency and lower flame speed of CNG.
4. Under the same engine operations and configurations, sequential port injection CNG operation shows 4-10% volumetric efficiency dropped due to the displacement of air by CNG in cylinder compared to gasoline.
5. The results also show that CNG in sequential port injection system yields improved BSFC and better FCE compared to carburetor system.
6. It is observed that Gas Injection system has more potential compared to Gas Mixture system.
7. Emission of pollutant gaseous from automotive engine is significantly reduced by the use of CNG with 40-87% reduction of unburned hydrocarbons.
8. The reduction of CO and CO_2 emission are 20-98% and 8-20% respectively by CNG.

9. CNG is highly attractive fuel for vehicles and will become more important due to the increasing demand of cleaner fuels and ever tightening emission norms.
10. CNG is far more affordable than the commonly used fuels like petrol and diesel and can lead to significant cost savings.
11. Since the common practice is to modify existing petrol and diesel engines to CNG, optimization of the engine for CNG as fuel is very difficult or not possible. Dedicated CNG engines can further increase the performance of the vehicles.
12. CNG has a very high octane number (< 130) compared to petrol and hence higher compression ratio can be utilized to improve the engine performance and increase its efficiency.
13. NOx emissions can be drastically reduced by blending small quantities of hydrogen gas with the CNG. It will also improve its thermal efficiency.
14. It is observed that duel fuel vehicle is not compatible for CNG.

Future Scope:

- To reduce Nox and NMHC if CNG is blended by hydrogen by some percent it shows reduction in emission and improvement in performance.
- For dual fuel engine results can be compared by varying compression ratio.
- Different results can be obtained by changing injection pressure, injection timing, Injector position, nozzle diameter etc.

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