International Journal of Advances on Automotive and Technology
Promech Corp. Press, Istanbul, Turkey
Vol. 1, No. 1, pp. 25-31 January, 2017

http://dx.doi.org/10.15659/ijaat.16.07.329
Manuscript Received May 14, 2016; Accepted June 11, 2016.

This paper was recommended for publication in revised form by Co-Editor Yasin Karagoz

EXPERIMENTAL INVESTIGATION ON USE OF CNG AND HONGE BIODIESEL IN A SINGLE CYLINDER DIESEL ENGINE

Noel D.
Thermal Power Engineering, Department of Mechanical Engineering, PDA College of Engineering, Kalaburagi-Karnataka, INDIA

S R Hotti
Department of Automobile Engineering, PDA College of Engineering Kalaburagi-Karnataka, INDIA

Omprakash Hebbal
Department of Mechanical Engineering, PDA College of Engineering Kalaburagi-Karnataka, INDIA

Keywords: CI engine, Dual fuel, CNG and HOME
E-mail address: noelddhanraj@gmail.com, hottisr@gmail.com, hebbalod@rediffmail.com

ABSTRACT

Drastic crises in the demand of energy made engineers to focus on different energy sources mainly to balance the lack of petroleum products by replacing the diesel with liquid and gaseous fuels as an alternate fuel. The objective of the present work is to evaluate compressed natural gas (CNG) and honge oil methyl ester (HOME) as a dual fuel mode in a compression ignition diesel engine. The experiment is carried out for pure diesel, neat honge biodiesel and HOME with constant CNG supply at rate of 0.29 kg/hr and 0.5 kg/hr respectively and it is observed that the brake thermal efficiency for 0.5 kg/hr CNG-HOME is 26.4% against 28.4% diesel at 75% of the load. The exhaust gas analysis showed CO and HC are higher at low load and gradually decreased with increase in the brake power for CNG flow rate of 0.29 kg/hr and 0.5 kg/hr with HOME. Engine operation in the dual fuel mode has lower NO_x emission and lower smoke compared to diesel and neat biodiesel. In dual fuel mode NO_x emission and smoke is lower for 0.5 kg/hr CNG flow rate which is optimum in the cases presented here, with a very little reduction in thermal efficiency.

INTRODUCTION

Increase in demand for petroleum fuels, global warming, ozone layer depletion, toxic emissions associated with petrol and diesel have caused researchers to search alternate clean burning liquid and gaseous fuels in internal combustion engines. Vegetable oil and their biodiesel are one of the most promising renewable sources of fuel. Many of the researches reported that using liquid fuels in a short term in internal combustion engine is very promising but using the liquid fuels in a long term engine tests results showed increase in the carbon built up and increase in the contamination of lubricating oil which results in the engine failure. The researchers concluded that engine failure can be prevented by using liquid fuels either blend with diesel or use in a dual fuel mode [1-2]. The availability of liquid alternate fuels in the market as for as now became quite small so the researchers found new promising alternative gaseous fuels such as hydrogen fuels, compressed natural gas (CNG), LPG and dimethyl ether [3-5]. Among the new alternative fuels CNG is potential for lower smoke, lower NO_x and low particulate emissions and also it is a clean burning fuel. Diesel engines are continuously producers of smoke and NO_x in their exhaust, this disadvantage can be solved by operating CI engine in a dual fuel mode. Compressed natural gas and honge biodiesel dual fuel operation is one of the best ways to reduce emissions from diesel engines [6-8]. In a dual fuel operation the CNG gaseous fuel is mixed with the air in intake manifold, the air fuel mixture is then compressed during compression stroke. Near the end of compression stroke honge biodiesel is injected as pilot fuel. After a short ignition delay the combustion of honge biodiesel occurs first igniting the CNG and flame propagation start [9-11]. The introduction CNG and honge biodiesel in cylinder have important effects on performance, emission and combustion characteristics of a dual fuel engine. Basavarajappa,et.al (2014) [12] conducted experiment on dual fuel engine using CNG, jathropha methyl ester and honge oil methyl ester and the performance, emission and combustion characteristics are evaluated and presented. In their work various parameters such as injection timing, compression ratio, CNG flow rate, exhaust gas recirculation (EGR) are varied on the performance of dual-fuel engine has been presented. From the experimental results they concluded that at a compression ratio of 17.5, injection timing of 27° BTDC, 10% EGR and 6 mm carburetor resulted in overall improved performance. Navindgi,et.al (2013) [13] Conducted experiment on a single cylinder diesel engine using CNG and neem oil blend and evaluated performance and emission characteristics. In their experiment for five different CNG flow rates varying from minimum flow rate to maximum flow rates. From the experimental results they concluded that CNG 4% and neem oil 96%, CNG 8% and neem oil 92%, CNG 12% and neem oil 88% are found to be optimum for performance and emission characteristics. Meyyappan Venkatesan,et.al (2013) [14] has conducted experiment on a single cylinder diesel engine using jathropha biodiesel and CNG in a dual fuel mode. Here the performance and emission characteristics are evaluated and presented. The experiment is conducted for different injection pressures and different injection timings such as 180, 200 and 220 bar, 27^{o}btdc and 31^{o}btdc. From the experimental results CNG - JOME gives better performance at 220 bar pressure and advanced injection timing of 31^{o}btdc. The emission parameters such as CO, UBHC and NO_x are reduced in JOME with CNG compared to diesel fuel. Ramjee,et.al (2012) [15] has conducted experiment on a single cylinder diesel engine using CNG and diesel in a dual fuel mode. In their work experiment is conducted at constant speed with varying injection pressures and load. From the experimental results showed better performance for CNG with diesel in dual fuel mode up to 75.67% load compared to diesel. This paper presents experimental analysis on performance, emission and combustion characteristics on a single cylinder diesel engine using CNG and honge biodiesel in dual fuel mode.

INTRODUCTION OF FUEL CHARACTERIZATION

CNG is supplied to the engine through intake manifold with inhaled air. Biodiesel is used as honge oil methyl ester (HOME) is used as a pilot fuel. Table 1 and 2 shows properties of HOME and CNG respectively.

Table 1: Fuel Properties

Fuel properties	Diesel	HOME
Kinematic viscosity at 40^{0} C (cst)	3.9	14.7
Calorific value (kJ/kg)	43000	40500
Density (kg/m^3)	830	890
Flash point (^{0}C)	56	196
Fire point (^{0}C)	65	206

Table 2: CNG Properties

Properties	CNG
Molecular mass	16.01
Density (kg/m^3)	0.65
Normal boiling point (K)	0.77
Flammability limits in air (%)	5-15
Burning velocity (cm/s)	45
Adiabatic flame temperature (K)	2148
Stoichiometric composition vol (%)	9.48
Min. ignition temperature (mJ)	0.29
Auto ignition temperature (K)	813
Calorific value (MJ/kg)	45.8
Quenching gap in air (cm)	0.203
Normalized flame emissivity	1.7
Equivalence ratio	0.7-4
% of thermal energy radiated	22-33

Figure 1 shows the schematic diagram and Figure 2 shows the photograph of the experimental setup. Also the engine specification is given in table 3. The experiment has been conducted by using pure diesel, pure HOME and CNG with HOME (dual fuel mode) for variable loads like 0,1,2,3,4,5.2 kW at constant rated speed of 1500 rpm. For dual fuel mode (CNG and HOME) two sets of readings were taken by supplying CNG at the rate of 0.29 kg/hr and 0.5 kg/hr with HOME. The conventional gas fumigation technique is used for mixing the CNG with the intake air through a cross flow mixing chamber added before the intake manifold. Gas could be used from the low pressure CNG unit. A calibrated gas flow meter is used to measure the natural gas consumption rate.

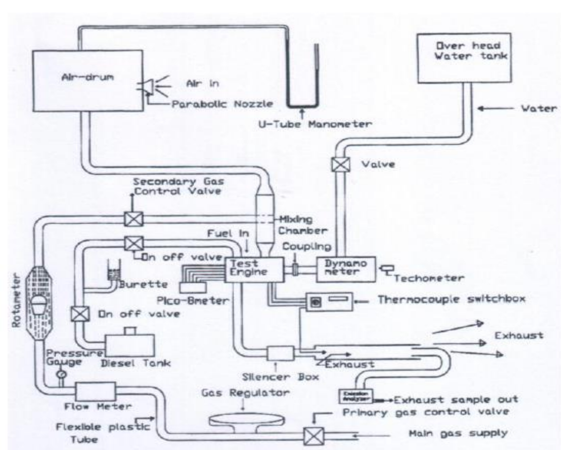

Fig. 1: Schematic diagram of the experimental setup.

Fig. 2: Photograph of the experimental setup

Table 3 Engine Specifications

Manufacturer	Kirloskar oil engines Ltd, India
Model	TV-SR, naturally aspirated
Engine	Single cylinder, DI
Bore/stroke	87.5mm/110mm
Compression ratio	17.5:1
Speed	1500r/min, constant
Rated power	5.2 kW
Working cycle	four stroke
Injection pressure	200bar/23 deg before TDC
Type of sensor	Piezo electric
Response time	4 micro seconds
Crank angle sensor	1-degree crank angle
Resolution of 1 deg	360 deg with a resolution of 1deg

RESULT AND DISCUSSION

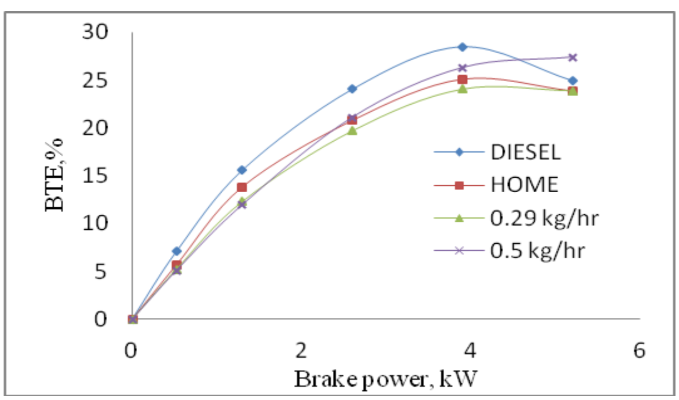

Figure 3 Variation of brake thermal efficiency with brake power

Fig. 3 shows variation of brake thermal efficiency with brake power for diesel, neat honge biodiesel, honge biodiesel-CNG dual fuel at 0.29 kg/hr and 0.5 kg/hr CNG flow rate. Brake thermal efficiency increases with increase in brake power for all fuels tested. The maximum brake thermal efficiency of biodiesel is 25.09% against that of diesel 28.5% at 75% of the load. In dual fuel mode for the CNG flow rate of 0.29 kg/hr and 0.5 kg/hr with biodiesel is lower at low loads, however at higher loads increases with increase percentage of CNG. The maximum efficiency for 0.5 kg/hr CNG-biodiesel is 27.4% against 23.87% neat biodiesel at full load.

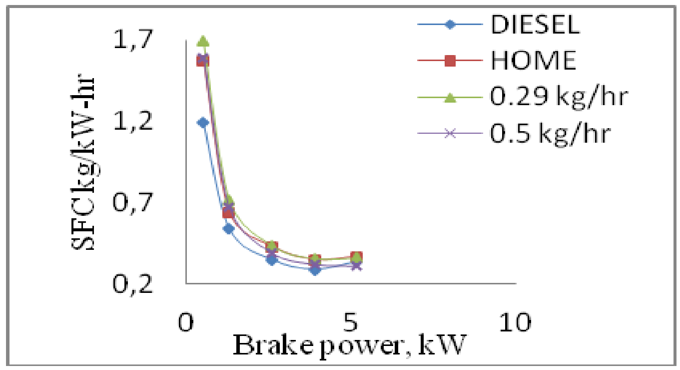

Figure 4 Variation of specific fuel consumption with brake power

Figure 4 shows variation of specific fuel consumption with brake power for diesel, neat honge biodiesel, honge biodiesel-CNG dual fuel at 0.29 kg/hr and 0.5 kg/hr CNG flow rate. Specific fuel consumption decreases with increase in brake power for all fuels tested. Minimum specific fuel consumption of biodiesel is 0.35 kg/kW-hr against 0.29 kg/kW-hr for that of diesel at 75% of the load. In the dual fuel mode for CNG flow rate of 0.29 kg/hr and 0.5 kg/hr with biodiesel, SFC is higher at low loads, however at higher loads decreases with increase in percentage of CNG. The minimum specific fuel consumption for 0.5 kg/hr CNG-biodiesel is 0.31 kg/kW-hr against 0.37 kg/kW-hr neat biodiesel at full load.

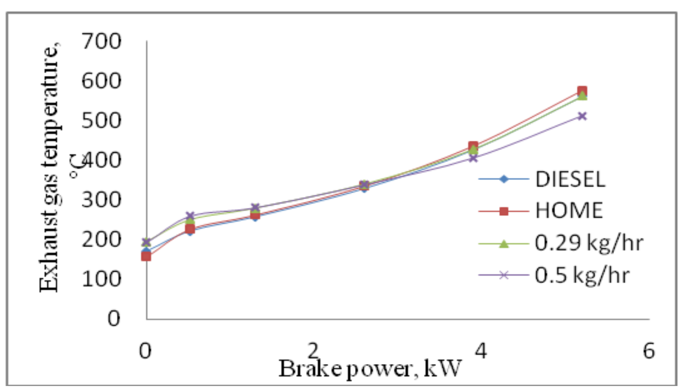

Fig. 5: Variation of exhaust gas temperature with brake power

Fig. 5 shows variation of exhaust gas temperature with brake power for diesel, neat honge biodiesel, honge biodiesel-CNG dual fuel at 0.29 kg/hr and 0.5 kg/hr CNG flow rate. Exhaust gas temperature increases with increase in brake power for all fuels tested. At part load exhaust gas temperature is almost same for all tested fuels and at full load the exhaust gas temperature is higher for neat biodiesel. In the dual fuel mode at full load, the exhaust gas temperature for CNG flow rate of 0.29 kg/hr with biodiesel is higher than that of CNG 0.5 kg/hr with biodiesel. The maximum exhaust gas temperature for 0.29 kg/hr CNG-biodiesel is 561.65°C against 511.89°C CNG-biodiesel 0.5 kg/hr at full load and maximum gas temperature compared to that of diesel is 562.67°C.

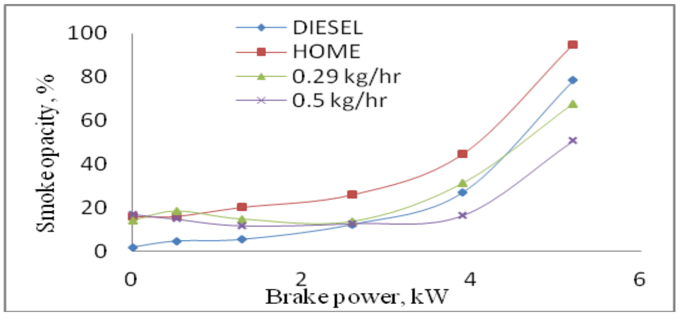

Fig. 6: Variation of smoke opacity emissions with brake power

Fig. 6 shows variation of smoke opacity emissions with brake power for diesel, neat honge biodiesel, honge biodiesel-CNG dual fuel at 0.29 kg/hr and 0.5 kg/hr CNG flow rate. The smoke opacity of biodiesel is higher than that of diesel but trend for both of them remains same. Upto 75% of the load the smoke emission is almost constant. From 75% to full load, there is a sharp increase in the smoke emission of all fuels under test. The maximum smoke emission of biodiesel is 94.9% against 70.34% of that of diesel. However the dual fuel mode increase in CNG flow rate reduces the smoke. The maximum smoke emitted for 0.29 and 0.5 kg/hr flow rate of CNG-biodiesel is respectively 67.78% and 50.68%.

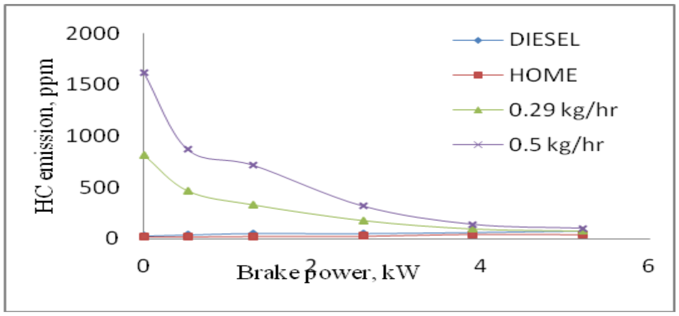

Fig. 7: Variation of HC emissions with brake power

Fig. 7 shows variation of HC emissions with brake power for diesel, neat honge biodiesel, honge biodiesel-CNG dual fuel at 0.29 kg/hr and 0.5 kg/hr CNG flow rate. At part load HC emissions remains almost same for diesel and neat biodiesel and at full load HC emission is a little higher for diesel. Maximum unburnt hydro carbon emission is for dual fuel mode. At no load 0.5 kg/hr and 0.29 kg/hr CNG-biodiesel dual fuel is of the order of 1621.8 ppm and 816.4 ppm respectively. As the load increases unburnt hydro carbon considerably reduces and from 75% load onwards it is of the order of that of the diesel.

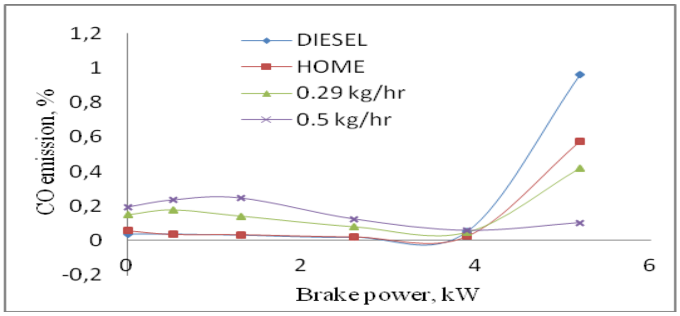

Fig. 8: Variation of CO emissions with brake power

Fig. 8 shows variation of CO emissions with brake power for diesel, neat honge biodiesel, honge biodiesel-CNG dual fuel at 0.29 kg/hr and 0.5 kg/hr CNG flow rate. At part load CO emissions remains almost same for diesel and neat biodiesel and at full load CO emission is higher for biodiesel than that of diesel. The maximum CO emission of neat biodiesel is 0.576% against that of diesel 0.961% at full load. In the dual fuel mode at full load, the CO emission for CNG flow rate of 0.29 kg/hr with biodiesel is higher than that of CNG 0.5 kg/hr with biodiesel. The maximum CO emission for 0.29 kg/hr CNG-biodiesel is 0.42% against 0.10% CNG-biodiesel 0.5 kg/hr at full load.

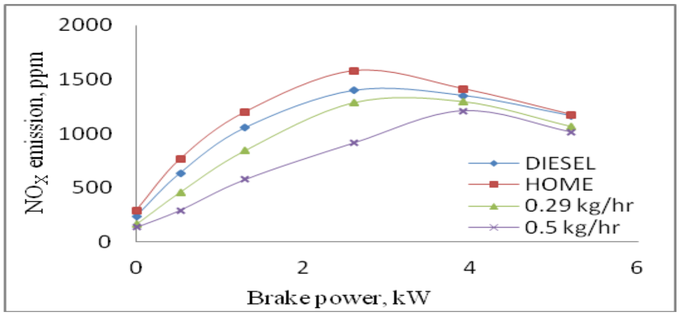

Fig. 9: Variation of NO_x emissions with brake power

Fig. 9 shows variation of NO_x emissions with brake power for diesel, neat honge biodiesel, honge biodiesel-CNG dual fuel at 0.29 kg/hr and 0.5 kg/hr CNG flow rate. The NO_x emission increase with increase in brake power upto a certain load and gradually decreases for all tested fuels. The NO_x emission for biodiesel is higher than that of diesel. The maximum NO_x emission of neat biodiesel is 1579.68 ppm against that of diesel 1399.47 ppm. In the dual fuel mode at full load, the NO_x emission for CNG flow rate of 0.29 kg/hr with biodiesel is higher than that of CNG 0.5 kg/hr with biodiesel.

The maximum NO_x emission for 0.29 kg/hr CNG-biodiesel is 1068.64 ppm against 1014.37 ppm CNG-biodiesel 0.5 kg/hr at full load.

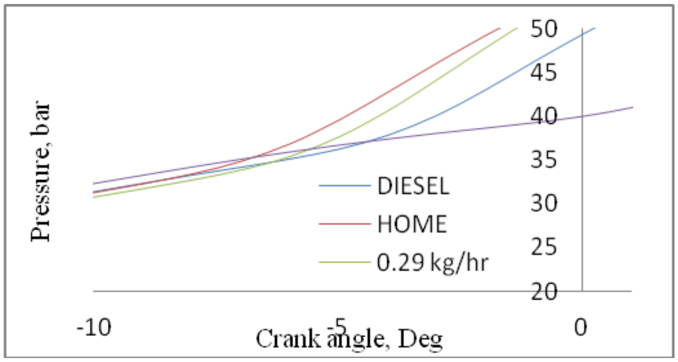

Fig. 10 (a): Variation of pressure with crank angle

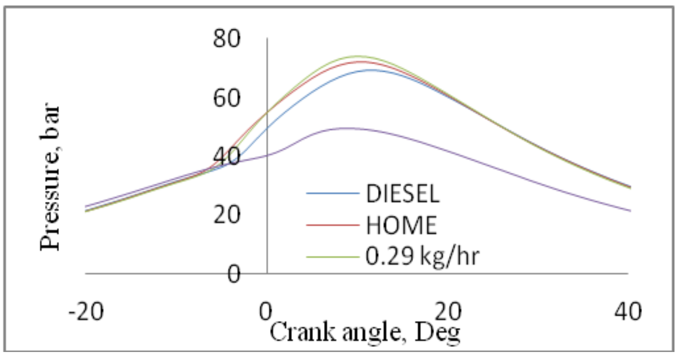

Fig. 10 (b): Variation of pressure with crank angle

Fig. 10 (a) and Fig. 10 (b) shows variation of cylinder pressure with crank angle for diesel, neat honge biodiesel, honge biodiesel-CNG dual fuel at 0.29 kg/hr and 0.5 kg/hr CNG flow rate. The higher cylinder pressure was observed at honge biodiesel-CNG flow rate of 0.29 kg/hr compared to diesel. The maximum cylinder pressure for 0.5 kg/hr CNG-biodiesel, diesel, neat biodiesel and 0.29 kg/hr CNG-biodiesel is 49.32, 69.38, 72.29 and 73.86 bar respectively. However the rate of change of pressure with respect to crank angle is more for diesel than that of other fuel combinations.

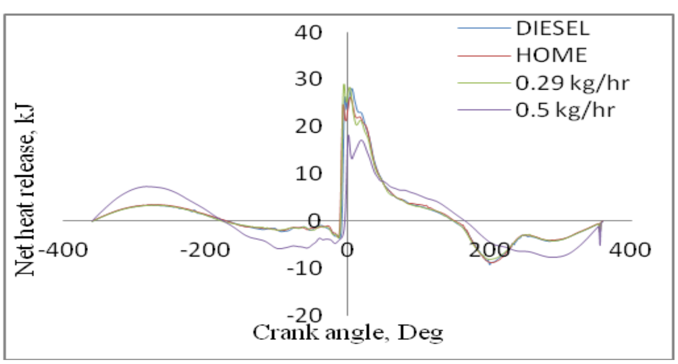

Fig. 11: Variation of net heat release with crank angle.

Fig. 11 shows variation of net heat release with crank angle for diesel, neat honge biodiesel, honge biodiesel-CNG dual fuel at 0.29 kg/hr and 0.5 kg/hr CNG flow rate. Higher heat release rate is observed for biodiesel- CNG flow rate of 0.29 kg/hr compared to diesel, neat biodiesel and biodiesel-CNG flow rate of 0.5 kg/hr. The maximum net heat release rate for 0.29 kg/hr CNG-biodiesel is 28.93 kJ at -4° crank angle against 18.32 kJ 0.5 kg/hr CNG-biodiesel at 2° crank angle, 26.17 kJ neat biodiesel at 5° crank angle and 28.2 kJ diesel at 6° crank angle respectively.

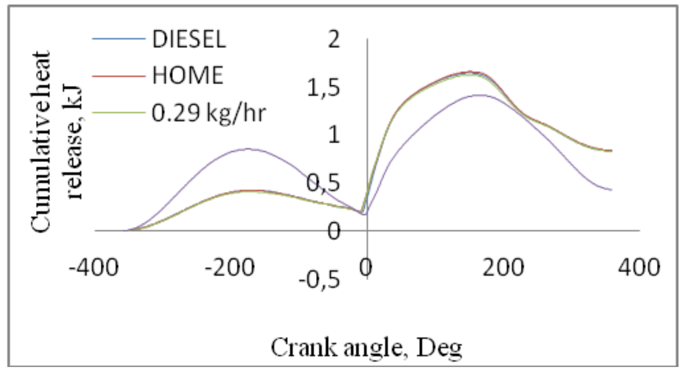

Fig. 12 Variation of cumulative heat release with crank angle

Fig. 12 shows variation of cumulative heat release with crank angle for diesel, neat honge biodiesel, honge biodiesel-CNG dual fuel at 0.29 kg/hr and 0.5 kg/hr CNG flow rate. Higher cumulative heat release rate is observed for neat biodiesel compared to diesel, biodiesel-CNG flow rate of 0.29 kg/hr and biodiesel-CNG flow rate of 0.5 kg/hr. The maximum cumulative heat release rate for neat biodiesel is 1.65 kJ at 140° crank angle against 0.29 kg/hr CNG-biodiesel is 1.62 kJ at 137° crank angle, 1.42 kJ 0.5 kg/hr CNG-biodiesel at 155° crank angle and 1.64 kJ diesel at 144° crank angle respectively.

From the pressure crank angle diagram (Fig. 10(a) and 10(b)) we observe that honge biodiesel starts combustion at 8° before TDC but diesel starts at 6° before TDC the ignition lags lower for biodiesel, since inbuilt oxygen content of biodiesel makes advancement in combustion. However rate of pressure rise with respect to crank angle is more in diesel. Because of lower density of diesel form the fine spray in the combustion chamber. Also we observe that combustion takes early in the premixed combustion phase even for biodiesel. Because of this complete combustion takes place for both the fuels. From Fig. 8 we observe that up to 75% of the load CO emission is lower and closely matches for biodiesel and diesel. After 75% load to full load CO emission is lower for biodiesel because of its inbuilt oxygen content. Further in addition of CNG reduces CO at higher load since CNG is gaseous fuel burns completely. From Fig. 7 we observe that hydrocarbon emission for biodiesel and the diesel are very low for full load of operation, however in addition of CNG with biodiesel increases HC emissions at lower loads. As the load increases unburnt HC comes closer to the biodiesel and that of diesel [full load], this could be because of lean mixture of CNG at lower loads. From figure 6 we observe that Smoke opacity of biodiesel is higher than that of diesel and have the same trend for full load of operation because of higher density the droplet sizes are higher in addition to lower calorific value more smoke forms in biodiesel. By increasing the percentage of CNG in dual fuel mode assures clean burning, so smoke emission reduces. From Fig. 9 we observe NO_x emission for both biodiesel, diesel increases and then decreases. NO_x emission for biodiesel is higher for entire range of operation than that of diesel. From Fig. 11 and 12 we observe that net heat release rate and cumulative heat release rate we can observe that temperature in combustion chamber for both biodiesel and diesel are higher but NO_x emission of biodiesel is higher than that of diesel because of inbuilt oxygen content of the biodiesel which readily forms the NO_x. However at higher loads air fuel mixture is rich, which lowers the availability of oxygen. As the percentage of CNG in the dual fuel mode increases NO_x emission reduces due to higher stoichiometric air fuel ratio of CNG. Engine operation in the dual fuel mode has lower NO_x emission with respect to neat biodiesel. CNG-biodiesel dual fuel mode NO_x emission is lower for 0.5 kg/hr CNG flow rate which is optimum in the cases presented here in this work with a very little reduction in thermal efficiency.

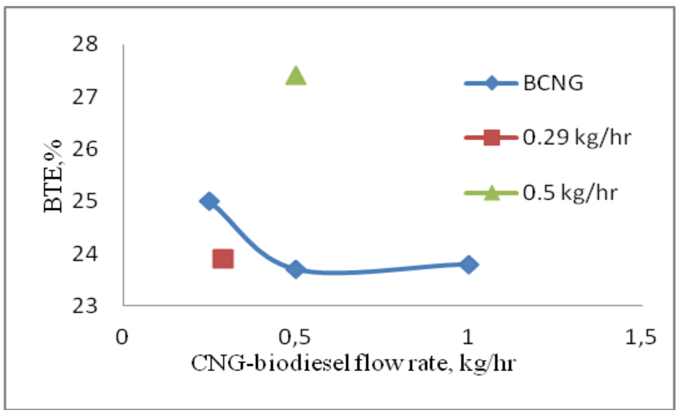

Fig. 13: Variation of brake thermal efficiency with CNG-biodiesel flow rates

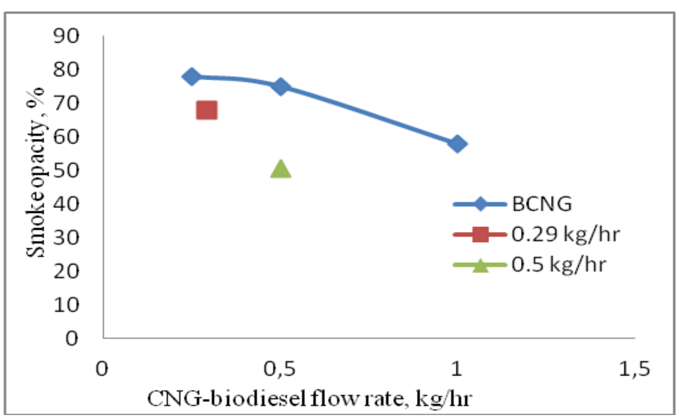

Fig. 14: Variation of smoke opacity with CNG-biodiesel flow rates

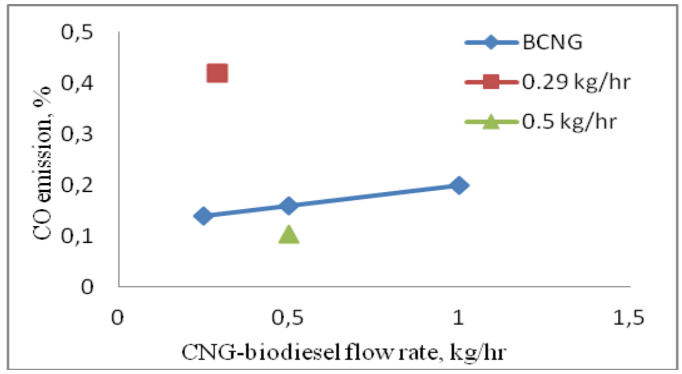

Fig. 15: Variation of CO with CNG-biodiesel flow rates

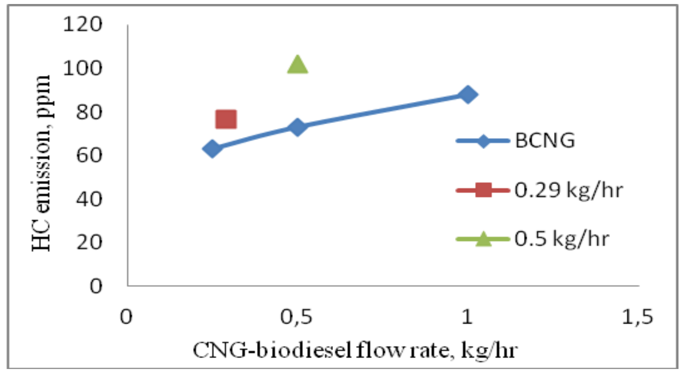

Fig. 16: Variation of HC with CNG-biodiesel flow rates

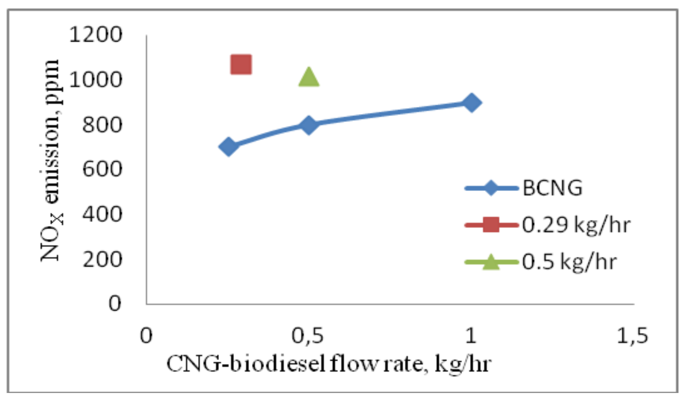

Fig. 17: Variation of NO_x with CNG-biodiesel flow rates

Validation of current work is compared with the similar work Basavarajappa et.al available in the literature. He used same engine i.e. single cylinder, water cooled, naturally aspirated kirloskar make 5.2 kW at 1500 rpm. Basavarajappa et.al conducted experiment on diesel, honge and jatropha biodiesel with CNG in a dual fuel mode at 0.25, 0.5 and 1 kg/hr CNG flow rates. The results available for honge biodiesel-CNG and jatropha biodiesel-CNG are compared with that of diesel-CNG in a dual fuel mode. From figure 13 to figure 17 shows variation of brake thermal efficiency, smoke, HC, CO and NO_x with respect to different CNG flow rates in dual fuel mode and current experimental values of this project. It is observed that smoke (fig 14), unburnt hydrocarbon (fig16) and CO emissions (fig15) are higher in current work for 0.29 kg/hr CNG-honge biodiesel compared to that of results of Basavarajappa et.al. Because of this, for 0.29 kg/hr CNG-honge biodiesel brake thermal efficiency (fig13) is lower than that of basavarajappaet.al. However the scenario is different for the case of 0.5kg/hr CNG-honge biodiesel case. Smoke emission (fig14) CO emissions (fig15) are much lower for 0.5 kg/hr CNG-honge biodiesel and a little increase in unburnt hydrocarbon. Reduction in smoke and reduction of CO indicates the combustion is complete and perfect hence 0.5 kg/hr CNG-honge biodiesel in current work has got higher brake thermal efficiency (Fig. 13) than that of Basavarajappa et.al. However NO_x emission are little higher for both the cases considered in my work.

CONCLUSION

In this project experimentation is carried out on a single cylinder water cooled naturally aspirated Kirloskar make 5.2 kW at 1500 rpm. The engine is operated on a dual fuel mode with CNG and biodiesel as fuels. The experiments were conducted for neat biodiesel 0.29 kg/hr CNG-biodiesel, 0.5 kg/hr CNG-biodiesel and the results are compared with that of pure diesel. Performance, emission and combustion characteristics of these fuels are evaluated and presented. From this work the following conclusions are drawn.

- Honge biodiesel is collected and characterisation is carried out. Density, viscosity, flash point, fire point are higher and calorific value is lower for this biodiesel compared to that of diesel because of inbuilt oxygen content honge biodiesel catches fire earlier than that of diesel. I.e. ignition lag of biodiesel is lower than that of diesel.
- Smoke emission reduces with increase in percentage of CNG in a dual fuel mode.
- CO emission reduces with increase in quantity of CNG in dual fuel mode.
- Unburnt hydrocarbon is higher at lower loads and decreases as the load increases in dual fuel mode.
- NO_x emission is higher for neat biodiesel and is the order of 1579.68 ppm. Increase in percentage of CNG reduces the NO_x considerably.
- 0.5 kg/hr CNG-biodiesel dual fuel has lower emissions with a little sacrifice in brake thermal efficiency.
- The experimental result of this project with the similar work available in the literature is found that results of this work are well comparable with basavarajappa, et.al and hence it validates.

REFERENCES

1. Demirbas Ayhan, (2005), Biodiesel production from vegetable oils via catalytic and non-catalytic supercritical methanol transesterification methods. Progress in Energy and Combustion Science, 31, 466-487.
2. Murugesan. A, Umarani C, Subramanian R, Nedunchezhian N (2009): Biodiesel as an alternative fuel for diesel engines- A Review. Renewable and sustainable energy reviews, volume 13, issue 3, pages 653-662.
3. Department of Energy: Alternative Fuels Data Center, Biodiesel.
4. Ranbir singh, sagar maji, ranbir singh "performance and exhaust gas emissions analysis of direct injection cng-diesel dual fuel engine".
5. Munde Gopal G., Dr. Dalu Rajendra S. Compressed natural gas as an alternative fuel: review International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 6, December 2012
6. P. M. Darade, R. S. Dalu Investigation of performance and emissions of CNG fuelled VCR engine International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 1, January 2013)
7. Ioan, S.,On the future of biodegradable vegetable lubricants used for industrial tribo systems‖, Gal I Fascicie VIII, 2002, Issue No. 1221-4590.
8. V.M. Domkundwar, "A course in internal combustion engines" Dhanpat Rai publication, ISBN 81-7700-003-0,pp 22.22-22.32.
9. G.D. Rai,"Non conventional energy sources" Khanna publishers, ISBN 81-7409-073-8, pp 315-615.
10. Zhao,J., Ma,F., Xiong,X., Deng,J., Wang,L., Naeve,N., Zhao,S.,2013. Effects of compression ratio on the combustion and emission of a hydrogen enriched natural gas engine under different excess air ratio. Energy. 59, 658-665.
11. Ranbir singh, sagar maji, ranbir singh "performance and exhaust gas emissions analysis of direct injection CNG-diesel dual fuel engine"
12. Y.H.Basavarajappa, N.R.Banapurmath, A.J. Sangameshwar performance, combustion and emission characteristics of a dual fuel engine operated with compressed natural gas (CNG) and honge and jatropha biodiesels. Universal journal of petroleum sciences (2014), 46-73.
13. M C Navindgi, Dr. Maheswar dutta, Dr. b. Sudheer prem kumar experimental investigation of "Performance and emission characteristics of CI engine using CNG and neem oil blend" international journal of advanced trends in computer science and engineering, vol.2 no.6, pages: 01-04 (2013).
14. Meyyappan Venkatesan "effect of injection timing and injection pressure on single cylinder diesel engine for better performance and emission characteristics for jatropa bio diesel in single and dual fuel mode with CNG".
15. E.Ramjee, K. Vijaya Kumar Reddy and J. Suresh Kumar" Performance Analysis of C I Engine with Dual Fuel Mode for different Speeds