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EFFECT OF INJECTION TIMING AND COMPRESSION RATIO ON THE PERFORMANCE OF LPG- HOME BIODIESEL DUAL FUEL ENGINE

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ABSTRACT

Diesel engines are found to emit more NOx and smoke emissions in addition to its rapid depletion. Hence it is very important to find a best alternate fuel, which can fully or partially replace diesel which emits fewer pollutants to the atmosphere from diesel engines. Dual fuel approach is a well established technique to make use of different types of fuels in diesel engines. In the present work, an experimental investigation has been conducted to perform the optimization studies on the dual fuel engine using LPG as primary fuel and HOME as pilot fuel on a DI Diesel Engine. The present work focuses on performance evaluation of compression ignition engine operated with LPG-Honge methyl ester (HOME) under dual fuel mode. Injection Timing was varied from 19^0 BTDC to 27^0 BTDC in steps of 4^0 BTDC. It was observed that, advancing the IT, dual fuel engine performance was improved, with reduced HC, CO and smoke emissions. However, the NOx emissions increased. The burning of LPG is facilitated with a pilot injection of HOME biodiesel. The viscosity of HOME biodiesel being twice that of diesel, it needs to be injected at higher IOP. Optimum IOP was found to be 230 bar. The LPG-HOME dual fuel engine resulted in overall better performance with advanced IT, increased IOP as well as increased number of nozzle orifices in the injector.

Keywords: *Diesel engine, HOME, Injection Timing, Injection Pressure, Compression ratio.*

1. INTRODUCTION

Diesel engines are the main prime movers for public transportation vehicles, stationary power generation units and for agricultural applications. Hence it is very important to find a best alternate fuel, which can fully or partially replace diesel which emits fewer pollutants to the atmosphere from diesel engines. In recent years, there has been a significant increase in research into the use of bio-fuels as a substitute for mineral fuels. Dual fuel approach is a well established technique to make use of different types of fuels in diesel engines. Dual fuel technology takes advantage of the inherent efficiencies of the compression stroke engine but with dramatically reduced consumption of diesel fuel [1-5]. This results in an engine that is both more powerful than a dedicated spark-ignited engine and with substantially better emissions than a dedicated diesel engine. The advantages of LPG in IC engines are reduced deposits, no fuel dilution of engine oil as observed in gasoline engine. Consequently, LPG engines have advantage of reduced cylinder wear and extended engine life. The potential benefits of using LPG in diesel engines are both economical and environmental. LPG consists of propane or butane or mixture of both: Unsaturated

propylene or butylene and trace quantities of ethane or pentane may be present is the commercial motor fuel used worldwide. In warmer climates, higher butane content gives satisfactory performance, whereas, high propane is necessary in cold climates. LPG has a high octane rating of 112 RON (100% propane) enabling the higher compression ratio to be employed in an engine design and thereby improving the thermal efficiency. Advancing the injection timing resulting in better engine performance has been reported in the literature. Many investigators have studied the effect of compression ratio on the performance and emission characteristics of diesel engine running on natural gas in dual fuel mode. Advancing the injection timing resulting in better engine performance has been reported in the literature. EGR is an effective technique to reduce NOx emissions in diesel engines. Many

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investigators have studied the effect of EGR on the performance and emission characteristics of diesel engine running on natural gas in dual fuel mode [6]. Effect of injection timing, compression ratio on the performance of LPG-HOME dual fuel has not been studied in detail.

2. CHARACTERIZATION OF HONGE, HOME AND LPG

In the present study HOME a biodiesel derived from the locally available honge oil is used as the injected pilot fuel and LPG as the inducted fuel. The honge oil is popularly known as pongamia or karanja oil. Among the non edible vegetable oils, the honge oil is considered as one of the better fuels for internal combustion engines [7-13]. It is also used as biodiesel when its viscosity is reduced by the method of trans-esterification. This oil was converted into its methyl ester known as HOME by the trans-esterification process. LPG consists of propane or butane or mixture of both: Unsaturated propylene or butylene and trace quantities of ethane or pentane may be present is the commercial motor fuel used worldwide. In warmer climates, higher butane content gives satisfactory performance, whereas, high propane is necessary in cold climates. LPG has a high octane rating of 112 RON (100% propane) enabling the higher compression ratio to be employed in an engine design and thereby improving the thermal efficiency. Properties of these fuels are listed in Tables 1 and 2.

Sl No	Properties	Diesel	Honge oil	HOME
1	Viscosity @ 40 ^{0}C (cst)	4.59	44.850	5.6
2	Flash point ^{0}C	56	270	163
3	Calorific Value in kJ / kg	45000	35800	36,010
4	Density kg / m3	830	915	890

Table 1: Properties of diesel, Honge oil and its methyl ester [12, 13]

Table 2: Properties of LPG

Flammability Limit	2.2 – 9.5%
Lean limit of Φ for LPG	0.515
Stoichiometric Air Fuel Ratio by mass	15.6
Air Fuel Ratio by mass at limits	29.9 and 6.93
Liquid Density at 15°C (g/cc)	0.582
Latent Heat (KJ/kg)	42500
Vapour Pressure at 38°C (bar)	13.3
Heating Value (KJ/kg)	46400
Volumetric Liquid Energy Density (kJ/lt) at atmospheric pressure and temperature	26800
Maximum possible leaning air (%)	91.6
Laminar Flame Speed (cm/s)	40
Octane Number (research)	>100
Boiling Point at atmospheric pressure (°C)	-42.18
Toxicity	Nil
Total System Efficiency (%) from production to utilization	6.0

Fig. 1.1 Experimental set up

Table 3 Specifications of Engine

Make and Model	Kirloskar, TV1
No. of Cylinders	One
Orientation	Vertical
Cycle	4 Stroke
Ignition System	Compression Ignition
Bore X Stroke	87.5mm X 110mm
Displacement Volume	660 cc
Compression Ratio	17.5:1
Arrangement of Valves	Overhead
Combustion Chamber	Open Chamber(Direct Injection)
Rated Power	5.2 kW (7 HP) @1500 rpm
Cooling Medium	Water cooled

The Injection Timing is varied by using shim plates at the pump base. The compression ratio of the diesel engine test rig is varied by moving the cylinder head up or down as shown in fig. 1.2.

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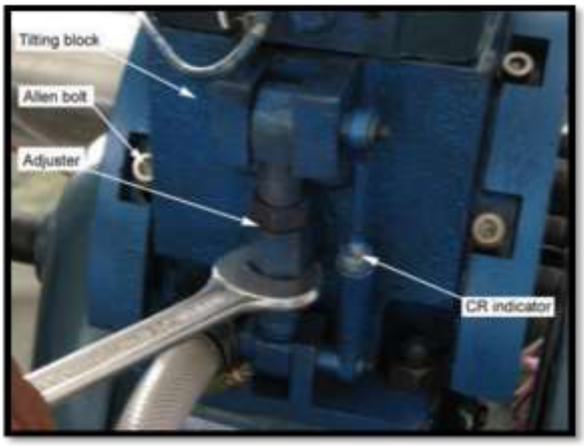

Fig. 1.2 Compression Ratio adjustments

Table 4 Specifications of smoke meter

Type	Hartridge Smoke Meter-4
Object of Measurement	Smoke
Measuring range opacity	0 – 100 %
Accuracy	+ / -2 % relative
Resolution	0.1 %
Smoke length	0.43 m
Ambient Temperature Range	-5^0 C to + 45^0 C
Warm up time	10 min. (self controlled) at 20^0C
Speed of Response Time	Within 15 sec. for 90% response
Sampling	Directly sampled from tail pipe
Power Supply	100 to 240 V AC / 50HZ, 10 – 16 V DC @15 amps
Size	100 mm x 210 mm x 50 mm.

Fig. 2 Smoke Meter

Table 5 Specifications of exhaust gas analyzer

Type	**DELTA 1600S**
Object of Measurement	Carbon monoxide (CO), Carbon Dioxide (CO_2) and Hydrocarbons (HC)
Range of Measurement	HC = 0 to 20,000 ppm as C_3H_8 (Propane) CO = 0 to 10%, CO_2 = 0 to 16% O_2 = 0 to 21% , NO_X = 0 to 5000 ppm (as Nitric Oxide)
Accuracy	HC = +/- 30 ppm HC CO = +/- 0.2% CO , CO_2 = +/- 1% CO_2 O_2 = +/- 0.2% O_2 ,NO_X = +/- 10 ppm NO
Resolution	HC = 1 ppm , CO = 0.01% V O_2 = 0.1% Vol.,NO_X = 1 ppm
Warm up time	10 min. (self controlled) at 20^0C
Speed of Response Time	Within 15 sec. for 90% response
Sampling	Directly sampled from tail pipe
Power Source	100 to 240 V AC / 50Hz
Weight	800 g
Size	100 mm x 210 mm x 50 mm

Fig. 3 Exhaust gas analyser

3. RESULTS AND DISCUSSIONS

This section provides the effect of injection timing on the performance of LPG–HOME/Diesel Dual Fuel operated Engine. The engine was operated at a constant speed of 1500 rpm and compression ratio of 17.5, Injection timing of 27°BTDC.
Constant LPG flow rate of 0.5 kg/hr was maintained. Biodiesel is injected with nozzle opening pressure of

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230 bars while 205 bars were maintained for Diesel, this is because the kinematic viscosity of biodiesel is nearly twice as that of diesel. The pressure of the injector is varied with the help of using nozzle tester. Nozzle Geometry of 4 holes 0.3mm diameter has been used.

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3.1 Brake Thermal Efficiency

This section deals with the variation of Brake Thermal Efficiency for various Gaseous fuels at 80 and 100% load. Figure 4 and 5 shows the variation of BTE for HOME-/LPG and diesel-LPG dual fuel operation at 80% and 100% load respectively. In that Higher brake thermal efficiencies is observed with HOME- LPG dual fuel operation. The reason for this increase in brake thermal efficiency is due to better combustion taking place inside the engine cylinder. Higher brake thermal efficiency of 26% was observed with HOME- LPG port injection dual fuel operation with biodiesel as pilot fuel.

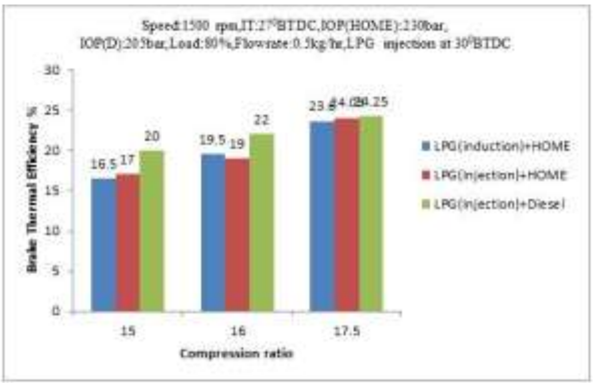

Fig. 4 Variation of BTE at 80% load

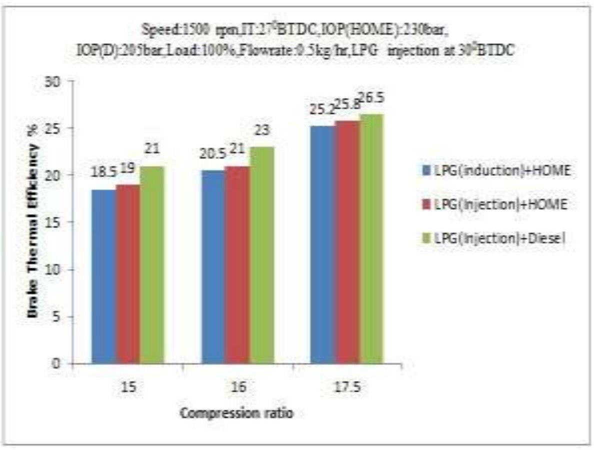

Fig.5 Variation of BTE at 100% load

3.2 SMOKE OPACITY

Figure 6 and 7 shows the variation of smoke opacity with injection timing for both 80% and 100% load respectively. The smoke opacity decreases with increase in injection timing. This is because of better combustion prevailing inside the engine cylinder. The inducted LPG-Biodiesel dual fuel results in higher smoke emission than injected LPG-Biodiesel fuel combination. Biodiesel being common the property of the gaseous fuels used is responsible for this trend. Heavy reduction in smoke is observed with LPG injection. This is because faster burning velocity of LPG facilitates quick burning of HOME droplets. The high viscosity of HOME leads to higher smoke compared to that of diesel-LPG operation.

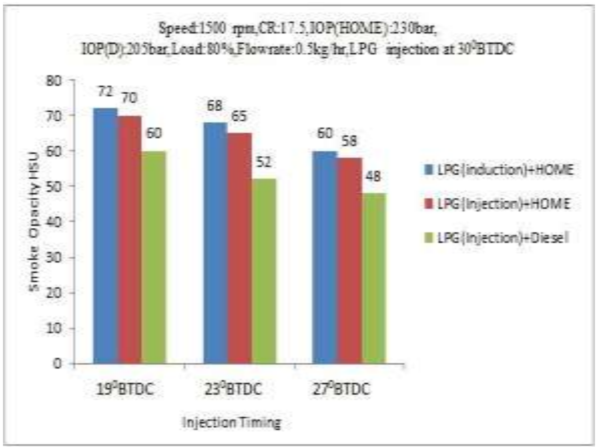

Fig. 6 Variation of smoke opacity at 80% load

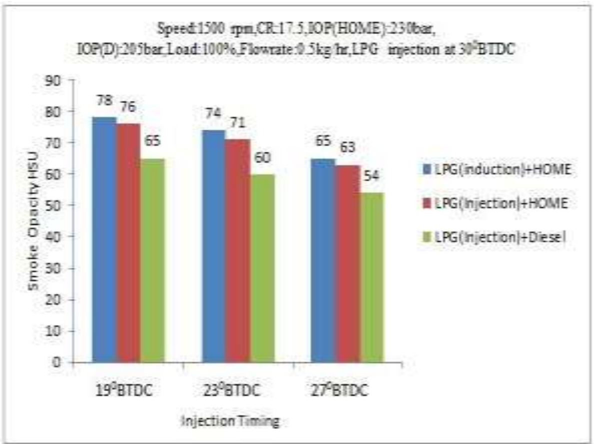

Fig. 7 Variation of smoke opacity at 100% load

3.3 HYDROCARBON EMISSION

Figure 8 and 9 shows variation of HC emissions with injection timings for HOME – LPG dual fuel combination operation. As the injection timing

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increases the emission decreases considerably as seen in the figure for both 80% and 100% loads. The reason for decreased HC emissions with increased injection timing could be due to better combustion with increased BTE and more heat released during premixed combustion. However other researchers reported that advancing injection timing showed low and high HC emissions at low and high loading conditions compared to the standard injection timing operation, respectively. With injection of LPG drastic reduction in HC were observed. This is because timed manifold injection of LPG results in complete combustion.

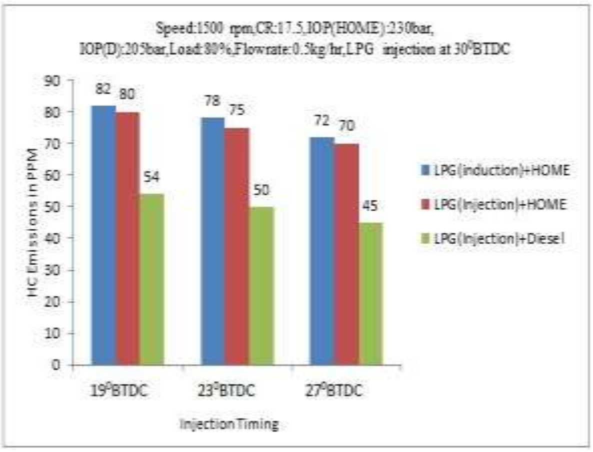

Fig. 8 Variation of HC at 80 % load

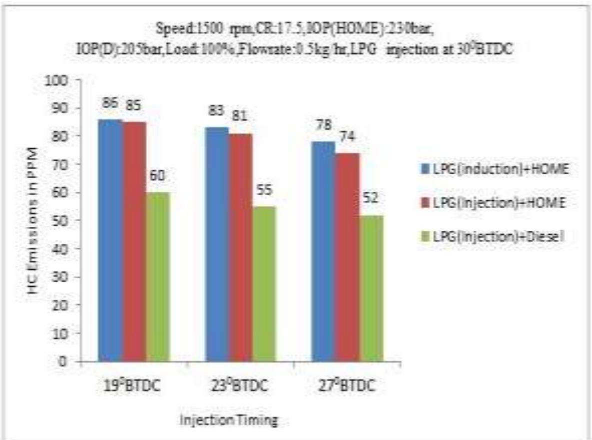

Fig. 9 Variation of HC at 100 % load

3.4 CARBON MONOXIDE EMISSION

Figure 10 and 11 shows variation of CO emissions with injection timings for HOME – LPG dual fuel operation for both 80% and 100% loads respectively. As the injection timing is advanced from 19^0 BTDC to 27^0 BTDC the CO emission also decreased considerably as seen in the figure. The emission of CO results from incomplete combustion of HC fuel. The emission of CO greatly depends on the air-fuel ratio relative to stoichiometric proportions. The reason for decreased CO emissions with increased injection timing could be due to better combustion with increased brake thermal efficiency. The advanced injection timing showed a significant reduction in CO emissions compared to standard dual-fuel operation. With injection of LPG drastic reduction in CO were observed. This is because timed manifold injection of LPG results in complete combustion.

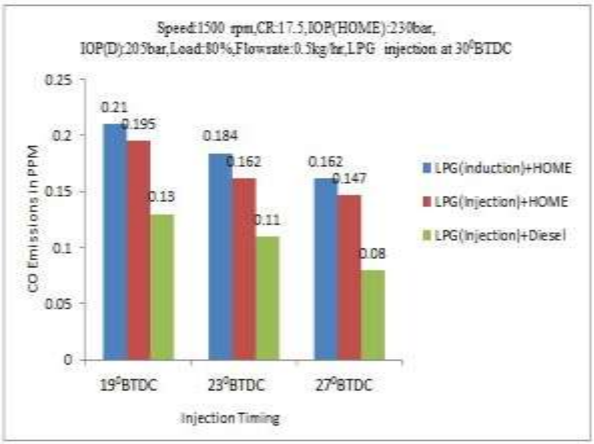

Fig. 10 Variation of CO at 80 % load

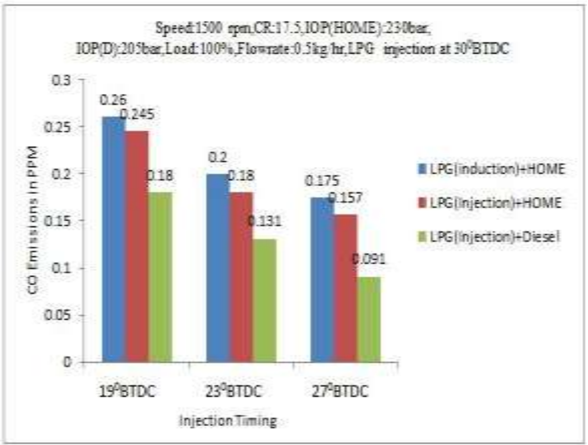

Fig. 11 Variation of CO at 80 % load

3.5 NO_x Emissions

Figure 12 and 13 shows variation of NOx emissions with injection timings for HOME – LPG fuel combinations respectively. As the injection timing increases the emission of NO_x increases considerably with the dual fuel combinations at both 80% and 100% load respectively. The reason for increased NO_x

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emissions with increased injection timing could be due to better combustion prevailing inside the engine cylinder and more heat released during premixed combustion. The higher NO_x emissions for 27^0 BTDC are later controlled by appropriate use of EGR method. The variations in NOx emissions follow changes in adiabatic flame temperature. These effects also vary with injection timing, suggesting that reaction zone stoichiometry and post combustion mixing are also influenced by fuel composition.

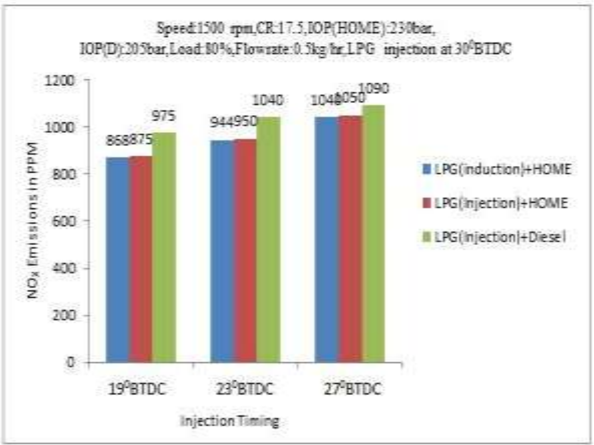

Fig. 12 Variation of NOx at 80 % load

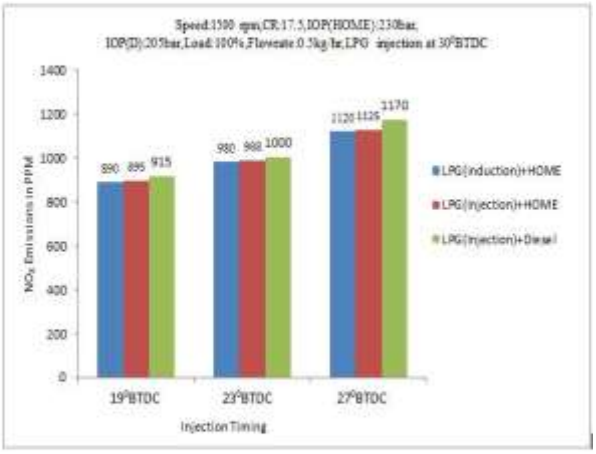

Fig. 13 Variation of NOx at 100 % load

4. CONCLUSIONS

Effect of Injection Timing suggest that with the advancement from 19^0 BTDC to 27^0 BTDC the brake thermal efficiency increased and smoke opacity, HC and CO emissions decreased. On the other hand NOx emission increased and is found to be maximum at 27^0BTDC. NOx can be controlled using EGR technique.

Effect of Compression Ratio shows that with the increasing compression ratio from 15 to 17.5 the brake thermal efficiency increased for both 80% and 100% loads. The smoke opacity, HC and CO emissions decreased. On the other hand the NOx emissions increase. The optimum compression ratios are found to be 17.5.

LPG biodiesels fueled dual fuel operation in both induction and injection modes resulted in poor performance compared to diesel operation. However, LPG injected dual fuel operation resulted in improved overall performance compared LPG inducted operation. It can be stated that port injection, as a methane supply method for dual fuel engines, is a very effective method to reduce unburned hydrocarbons and nitric oxides emissions. Shifting from homogeneous to port injection method, HC levels tend to decrease while NOx increase

REFERENCES

1. J Cao, Y Bian, D Qi, Q Cheng and T Wu, Comparative investigation of diesel and mixed liquified petroleum gas/diesel injection engines Proc. Instn Mech. Engrs Vol. 218 557-565, Part D: J. Automobile Engineering D10803© IMechE 2004.
2. Qi Donghui, Zhou Longbao, and Liu Shenghua (2005) Experimental studies on the combustion characteristics and performance of a naturally aspirated, direct injection engine fuelled with a liquid petroleum gas/diesel blend Proc. IMechE. Vol. 219, 253-261, Part D: J. Automobile Engineering
3. Chunhua Zhang, Yaozhang Bian, Lizeng Si, Junzhi Liao, and N Odbileg A study on an electronically controlled liquefied petroleum gas–diesel dual-fuel automobile Proc. IMechE. Vol. 219, D01604 © IMechE 2005, Part D: J. Automobile Engineering
4. Saleh H.E. Effect of variation in LPG composition on emissions and performance in a dual fuel diesel engine. Fuel 87 (2008) 3031–3039
5. Mohamed Y.E. Selim, M.S. Radwan, H.E. Saleh Improving the performance of dual fuel engines running on natural gas/LPG by using pilot fuel derived from jojoba seeds.
6. Ladommatos, N., et al., 1998. Effects of EGR on heat release in diesel combustion. SAE paper 980184.
7. Ertan Alptekin. Mustafa Canakci. "Characterization of the Key Fuel Properties of Methyl Ester–Diesel Fuel Blends". Fuel, Volume 88, Issue 1, 2009, Pages 75-80.
8. Pramanik K. (2003): Properties and use of Jatropha curcas oil and diesel fuel blends in compression ignition engine. International Journal of Renewable Energy, 28, Pages 239–48

International Journal of Emerging Technology and Advanced Engineering

Volume 3, Special Issue: ICERTSD 2013, Feb 2013, pages xxx-xxx

An ISO 9001:2008 certified Int. Journal, ISSN 2250-2459, available online at www.ijetae.com

9. Ashok M.P., Saravanan C.G., The Performance and Emission Characteristics of Emulsified Fuel in DI Diesel Engine, Proc IMechE. Vol. 221. Part-D. Journal of Automobile Engineering. 2005, Pages 893-900.
10. Canakci M., Performance and emission characteristics of biodiesel from soyabeen oil, Proc IMechE. Vol.219. Part-D, Journal of Automobile Engineering, 2005, Pages 915-922.
11. Gyeung Ho Choi, Seok Choun Bae, Sung Bin Han and Yong Jong Chung (2004) A study on the characteristics of combustion with butane and propane in a retrofitted diesel engine, Proc. Instn Mech. Engrs Vol. 218 Part D: J. Automobile Engineering 915-920, D06303 © IMechE 2004
12. Banapurmath N. R.; Tewari P. G.; Basavarajappa Y. H.; Yaliwal, V.S., Performance of Honge (Pongamia pinnata) oil blends in a diesel engine. XIX NCICEC, Annamalai University, Chidambaram, India. 2005.
13. N.R. Banapurmath and P.G. Tewari, Performance studies of a low heat rejection engine operated on non-volatile vegetable oils with exhaust gas recirculation. 2009, International Journal of Sustainable Engineering, Francis and Taylor Publications. Vol. 2, No. 4, December 2009, 265–274.

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