Universal Journal of Petroleum Sciences **5 (2017), 37-46**
www.papersciences.com

Dual Fuel Engine Operated with Hydrogen Enriched Producer Gas & Honge Biodiesel

Chetan Baseganni, Naveen Dinakar, Syed Suhel*, Sushrut Halewadimath
Department of Mechanical Engineering, K.L.E.Institute of Technology, Hubballi, India
***Corresponding author: syedsuhel123@gmail.com**

Abstract
Diesel engines are highly efficient and rugged due to their high compression ratio and are widely used in transportation, agriculture and power generation sectors. The main disadvantage of diesel engines is that they emit higher particulate matter and NO_x emissions. The ever increasing cost of crude petroleum products, their rapid depleting nature and strict regulation norms laid down on tail pipe emission has necessitated search for suitable alternative and renewable fuels for diesel engines in automotive traction and power generation sectors. Renewable and alternative fuels have numerous advantages compared with fossil fuels as they are renewable and biodegradable and provide food and energy security and foreign exchange savings besides addressing environmental concerns and socioeconomic issues. By the current study, the main objective is to develop a dual fuel engine operated on low calorific value producer gas which is produced by the partial combustion of the woody biomass in a downdraft gasifier and suitable biodiesel (HONGE) in dual fuel mode. The producer gas will be enriched with hydrogen gas addition in varying proportion. A suitable carburetor will be designed to mix air, producer gas and hydrogen fuel combinations. Performance of the developed dual fuel engine will be optimized for improved brake thermal efficiency and reduced emissions of smoke, HC, CO and NO_x.

Key Word and Phrases
Diesel Engines, HONGE, Producer Gas, Brake thermal Efficiency, Carburetor, Emission.

1. Introduction

Diesel engines have become an important means for transport and power generation applications as they possess high thermal efficiency and have lower HC and CO emissions compared to gasoline engines. Many researches are carried to attain high thermal efficiency and emission characteristics of compression ignition engines without compensating their fuel consumption. An investigation was carried out on the effect of biodiesel blended fuels (biodiesel obtained from unpolished rice and soya bean) on atomization and combustion characteristics of common-rail single-cylinder engine. It was concluded that higher surface tension and viscosity of the biodiesel induces lower Weber number and thus decreases injection velocity of biodiesel-blended fuels. Combustion and emissions characteristics of Karanja biodiesel (KOME) blends and diesel were investigated at constant engine speed of 1500 rpm. In addition, comprehensive spray investigations were also carried out. The fuel injection duration decreases slightly with increasing biodiesel content in the biodiesel blend. Fuel injection duration drops and peak injection rate increases with increase in fuel injection pressure at inlet and combustion duration of KOME was found to be relatively longer than diesel [1]. Compression ignition (CI) engines posses high thermal efficiency as well as high power output with higher levels of soot and nitric oxide emissions. CI engines have an ability to utilize high-quality renewable fuels that can be obtained efficiently from biomass. Renewable and alternative fuels have edge over fossil fuels. Since biodiesels are clean fuel, it addresses environmental concerns, and socio-economic issues and also provide energy security and food [2]-[6]. Experimental tests were conducted on single cylinder diesel engine using biodiesel and blends and effect of different engine parameters on engine performance were investigated [2], [3], [7]-[9]. A study was conducted on investigation of combustion and emissions characteristics of sea lemon oil as a fuel. The results reveals that increase in the injector opening pressure from the rated value diesel 170 bar to 190 bar. Results in a significant improvement in performance and emissions characteristics with fuel as Sea lemon oil due to better spray formation and also increases brake thermal efficiency from 27.3%-29.1% [10]. To reduce PM and NO_x emission from diesel engines, study was performed using CNG DFC as a biodiesel fuel and considering the system as low temperature combustion technology for simultaneous reduction of pollutants which includes investigation on effect of pilot injection pressure on the characteristics of engine emission in a single cylinder diesel engine. Emission characteristics of a biodiesel engine operating with various percentage of hydrogen enriched gas with diesel (5%, 10%,20%, 30%, 40%, and 50% by volume).Results reveal that increase in the concentration of hydrogen with base diesel fuel reduces combustion time and ignition lag and the amount of CO released from the emission is reduced [11].The rapid depletion of fossil fuels and degradation of environment due to combustion of fossil fuels have caused resurgence of interest in finding alternative fuels. The evaluation of feasibility of using a variety of alternative fuel has been of utmost concern. Rapid progress in the direction of using biodiesel and producer gas for compression ignition will be undertaken in order to become independent of diesel. Hence present work evaluates such a combination of fuels towards total elimination of diesel fuel [12].

By the present research an attempt is made to develop dual fuel engine operated on low calorific value gas called producer gas produced by partial combustion of the woody biomass in a downdraft gasifier and HOME biodiesel in a duel fuel mode. A suitable carburettor is designed to mix air, producer gas and hydrogen fuel combination. Diesel engine is modified to operate in dual fuel mode operating on HOME biodiesel and producer gas fuel combinations to determine performance, emission and combustion characteristics of a single cylinder four stroke diesel engine and combustion characteristics of a single cylinder four stroke diesel engine fuelled with HOME biodiesels producer gas fuel combinations.

2. Experimental Setup

The engine tests were conducted on a computerized CI engine test rig. It is of Kirloskar, TV1 engine and made up of single cylinder, 4-stroke, water cooled, and high-speed engine. The engine is directly coupled with eddy current dynamometer that permits engine motoring fully or partially.

Fig. 1 Experimental Setup

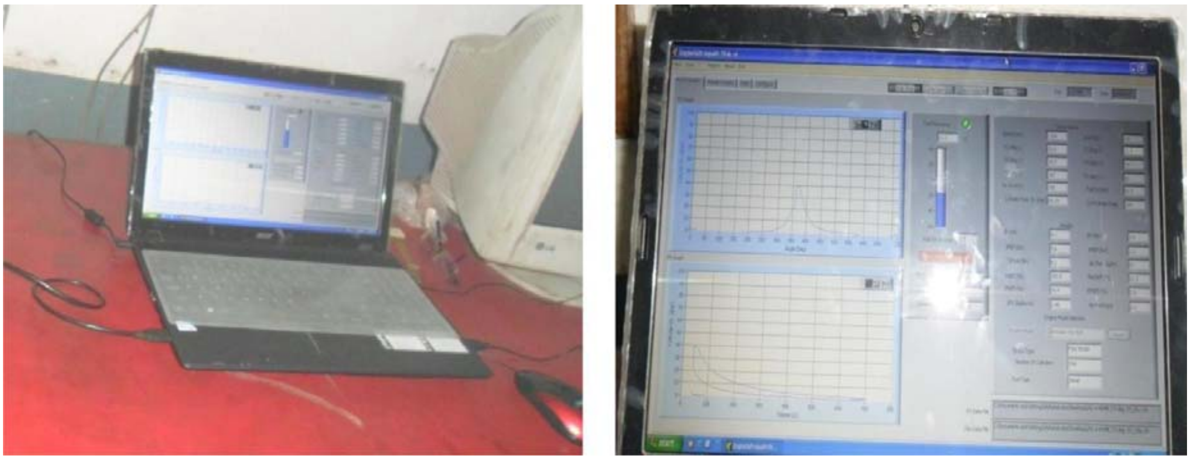

Fig. 2 Data Acquisition system

The engine and dynamometer were interfaced to a control panel which is connected to a digital computer. The computer software “Engine soft” was used in digital computer. The computer is used for recording the test parameters like fuel consumption, brake power, indicated power, brake thermal efficiency, BMEP, IMEP, volumetric efficiency, mechanical efficiency, EGT and peak pressure etc.

Fig. 3 HC & CO analyser **Fig. 4** Exhaust gas analyser

Table 1 Specifications of the 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 Ration	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

Table 2 Specifications of the down draft gasifier

Type	Downdraft gasifier
Supplier	Ankur Scientific Energy Technologies Pvt. Ltd., Baroda.
Rated capacity	62735 kJ/h
Rated Gas flow	15 Nm^3/h
Average gas calorific value	5-5.6 MJ/m^3
Rated woody biomass consumption	5-6 kg/h
Hopper storage capacity	40 kg
Biomass size	10 mm (Minimum) 50 mm (Maximum)
Moisture content (DB)	5 to 20%
Typical conversion efficiency	70-75%
Typical gas composition	$CO=19\pm3\%$, $CO_2=10\pm3\%$, $N_2=50\%$, $H_2=18\pm2\%$, CH_4=upto 3%

2.1 Proposed Design of Carburettor for Hydrogen-producer Gas Mixture

2.2.1. Design of Gas Carburettor

Step I: Determination of the volumetric intake of engine

Engine bore (D): 8.75 cm
Engine stroke (S): 11.0 cm
Rated speed (N): 1500 rev/min.
Maximum speed (120% of rated speed) (N'): 1800 rev/min.
Displacement volume = 661cc/cycle
Maximum (air + gas) intake under extreme conditions = $\frac{V_s \cdot N_1}{10^6 \cdot 2 \cdot 60}$
(Assuming 100% volumetric efficiency) = **0.009915 m^3/s**

Step II: Determination of mean intake velocity

Intake manifold diameter (D_i) = 0.029m
Cross sectional area of intake manifold (A_i) = 0.6605198 * 10^{-3} m^2
Therefore mean intake velocity

$$C_i = \frac{\text{Volume flow in } m^3/s}{\text{Cross sectional area } m^2} = \mathbf{15.0109\ m/s}$$

Step III: Determination of the air and gas quantities

Stichometric air to fuel ratio = 0.9044 N m^3/ N m^3
Stichometric air to fuel ratio at 30^0 C and 710 mm of Hg (at Hubli) = 0.9843332 m^3 of air / m^3 of gas
Therefore maximum gas intake = **0.0049966437 m^3/s**
Similarly maximum air intake = **0.00589848 m^3/s**

Density of producer gas at normal conditions = 1.1909 kg/m^3
Density of producer gas at 30^{0}C and 710 mm of Hg = 1.2961549 kg/m^3
Density of air at 30^{0}C and 710 mm of Hg = 1.0885208 kg/m^3
Mass flow rate of gas, m_g = **0.0064763676 kg/s**
Mass flow rate of air, m_a = **0.0064205311 kg/s**

2.2.2 Design of Venturimeter

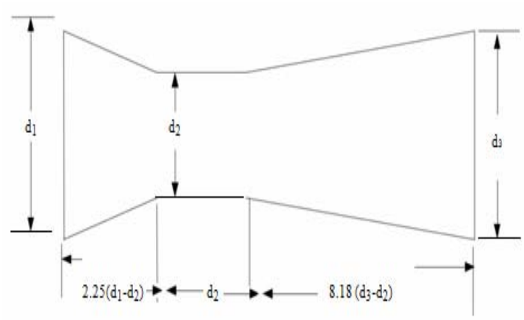

Fig. 5 Dimensions of a standard venturi

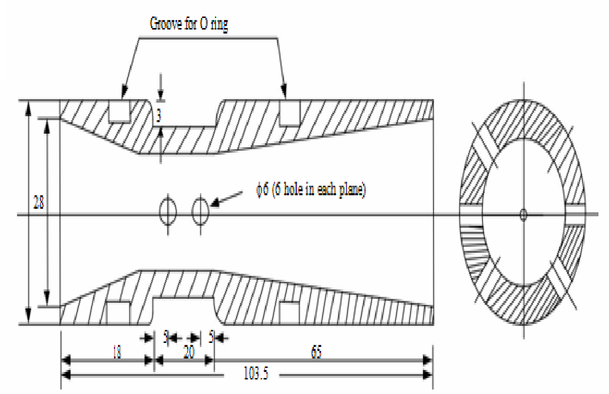

Fig. 6 Cross sectional view of venturi

Table 3 Properties of diesel, HOME

Sl No	Properties	Diesel	HOME
1	Viscosity (cSt at 40 °C)	2-3	5.3
2	Flash point (°C)	56	187
3	Calorific Value (kJ/kg)	45000	39798
4	Density (kg/m3)	830	909
5	Cetane Number	45-55	----
6	Cloud Point (^{0}C)	15	-1^0 C
7	Pour Point (^{0}C)	1	-8^{0}C
8	Carbon Residue (%)	0.1	0.01
9	Type of oil	Fossil fuel	Non edible

Table 4 Properties of hydrogen

Property	Hydrogen
Density at 1 atm and 300k (kg/m3)	0.082
Stoichiometric composition of air (% by volume)	29.53
No. of moles after combustion to before	0.85
Higher heating value (MJ/kg)	141.4
Lower heating value (MJ/kg)	1119.7
Higher heating value (MJ/m3)	12.10
Lower heating value (MJ/m3)	10.22
Combustion energy per kg of stoichiometric mixture (MJ)	3.37
Kinematic viscosity at 300k (mm^2/sec)	110
Thermal conductivity at 300 (mW/mK)	182
Diffusion coefficient in to air at NTP (cm^2/sec)	0.61
Flammability limits (% by volume)	4.75
Minimum ignition energy (mJ)	0.02
Laminar flame speed at speed at NTP (m/sec)	1.90
Adiabatic flame temperature (K)	2318
Auto ignition temperature (K)	858
Quenching gap at NTP (mm)	0.64
Stoichiometric fuel air mass ratio	0.029

Table 5 Stoichiometric air requirement calculation

Analysis	Fraction	Stoichiometric air ratio Nm^3/Nm^3	Air requirement
Carbon Monoxide	0.24	2.38	0.24*2.38=0.5712
Hydrogen	0.10	2.38	0.10*2.38=0.238
Methane	0.01	9.52	0.01*9.52=0.0952
			Total =0.9044

Table 6 Determination of density of producer gas

Analysis	Fraction present	Density kg/m^3	Density of Producer Gas kg/m^3
Carbon Monoxide	0.24	1.250	0.24*1.250=0.3000
Hydrogen	0.10	0.090	0.10*0.090=0.0090
Methane	0.01	0.717	0.01*0.717=0.0072
Carbon Dioxide	0.08	1.977	0.08*1.977=0.1582
Nitrogen	0.57	1.257	0.57*1.257=0.7165
	1.00		**Density =1.1909**

3. Results and Discussions

3.1 Brake Thermal Efficiency (BTE)

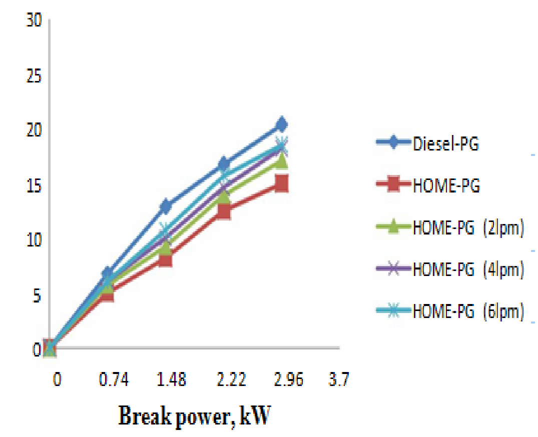

Fig. 7 Variation of brake thermal energy with brake power

Brake thermal efficiency (Fig. 7) is higher for blended producer gas dual fuel mode compared to HOME- producer gas operation over the entire load range. The injected biodiesel has higher viscosity than diesel which makes atomization difficult and also lowers calorific value which together results in lower BTE. Addition of hydrogen increases the BTE of the HOME-PG. Since hydrogen has very high calorific value the BTE increases with increased flow rate of hydrogen.

3.2 Smoke Opacity

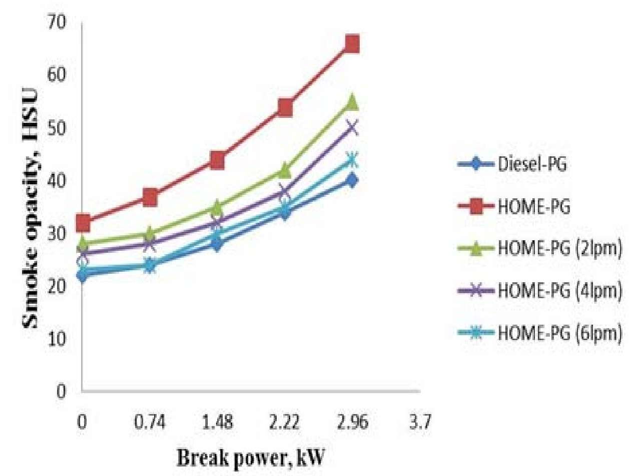

Fig. 8 Variation of smoke opacity with brake power

The smoke opacity is lower for Producer gas- diesel dual fuel operations compared to HOME - Producer gas over the entire load range (Fig. 8). Heavier molecular structure of the injected biodiesel when compared to diesel results in higher smoke levels. When hydrogen is added to HOME-PG dual mode, the smoke opacity is reduced. As the hydrogen flow rate increases the smoke opacity decreases due to lower molecular weight of hydrogen.

3.3 Hydrocarbon Emission

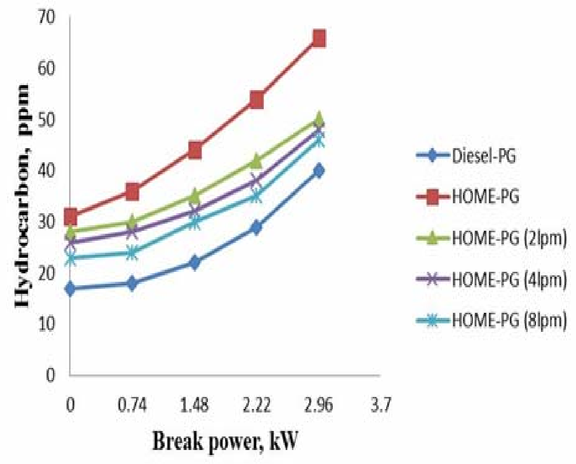

Fig. 9 Variation of hydrocarbon emission with brake power

The emission of hydrocarbons is minimal for the diesel-producer gas compared to HOME-PG over the entire load range (Fig. 9). When hydrogen is added to HOME-PG dual fuel mode the emission of hydrocarbons from the exhaust decreases as the flow rate of hydrogen is increased due to higher calorific value of hydrogen which enables complete combustion of the fuel.

3.4 Carbon Monoxide

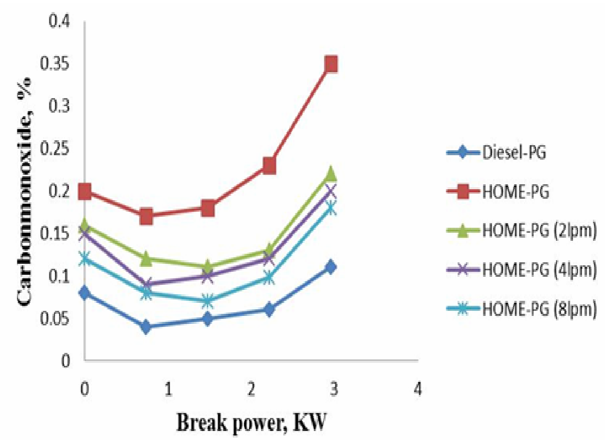

Fig. 10 Variation of carbon monoxide with brake power

The emission of carbon monoxide is lower for the diesel-producer gas compared to HOME-PG over the entire load range (Fig. 10). Lower emmissions of CO is the direct result of increased flowrate of hydrogen which enables complete combustion of the fuel.

3.5 Nitric Oxide (NO_X) Emission

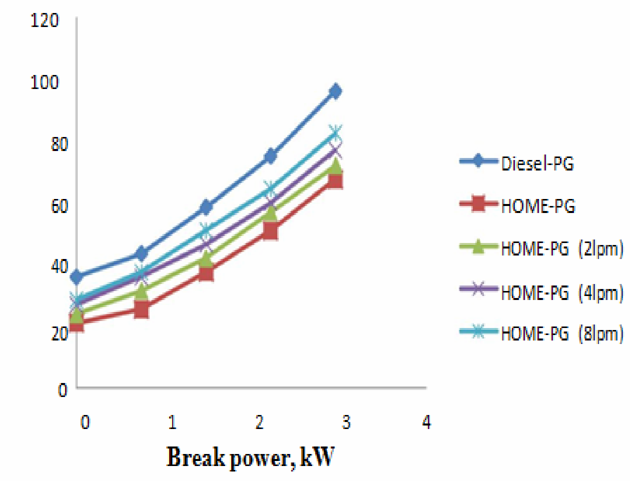

Fig. 11 Variation of emission of nitric oxide with brake power

The emission of nitric oxide is less for HOME-PG compared to diesel-producer gas over the entire load range (Fig. 11). When hydrogen is added to HOME-PG dual mode the emission of the nitric oxide is increased. As the hydrogen flowrate increases, the emission of nitric oxide gradually increases. Since hydrogen has higher calorific value it enables complete combustion of the fuel due to which the combustion temperature increases. Due to this increased temperature the emission of nitric oxide increases.

4. Conclusions

From the rigorous study it is concluded that the use of Hydrogen enriched producer gas as an alternative fuel along with HOME can perform better than HOME alone next to diesel fuelled engine. Furthermore, from the emission records it is observed that for higher amount of hydrogen addition there is reduction in HC, CO and Smoke from engine exhaust but NOx emission is higher for the same amount of hydrogen. This can be eliminated by installing a suitable catalytic convertor in the exhaust system which converts harmful combustion products into harmless by-products. Further work on the engine could involve modification with use of various biodiesels like rice bran oil and neem seed oil. Such high volatile biodiesel can be either directly injected into the engine manifold or can be blended by mixing with diesel. Incorporation of ECU (electronic control unit) in the existing system can increase the engine performance. By further research and study on the subject the use of diesel can be completely eliminated.

References

1. *Avinash Kumar Agarwal,* 'Effect of fuel injection pressure and injection timing on spray characteristics and particulate size–number distribution in a biodiesel fuelled common rail direct injection diesel engine', *Applied Energy,**130** (2014), 212–221.*
2. *Banapurmath N.R., Tewari P.G., Hosmath R.S.,* 'Combustion an emission characteristics of a direct injection, compression-ignition operated on Hongeoil, HOME and blends of HOME and diesel', *International Journal of Sustainable Engineering,* ***1*** *(2008), 80-93.*
3. *Banapurmath, N.R., Tewari P.G., Hosmath R.S.,* 'Effect of biodiesel derived from Hongeoil and its blends with diesel when directly injected at different injection pressures and injection timings in singlecylinder water-cooled compression ignition engine', *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy,* ***223*** *(2009), 31-40.*
4. *Banapurmath, N.R,. Marikatti,K.M., Hunashyal,A.M., and Tewari,P.G.,* 'Combustion characteristics of a four-stroke CI engine operated on Honge and Jatropha oil methyl ester-ethanol blends when directly injected and dual fuelled with CNG induction', *International Journal of Sustainable Engineering,* ***4*** *(2011), 145-152.*

5. *Lei, J., Bi Y., Shen L..,* ‘Performance and emission characteristics of diesel engine fueled with ethanol-diesel blends in different altitude regions’, *Journal of Biomedicine and Biotechnology Article,(2011), ID417421 doi:10.1155/2011/417421.*
6. *Karim, G.A.,* ‘An Examination of Some Measures for Improving the Performance of Gas Fuelled Diesel Engines at Light Load’, *Society of Automotive Engineers, (1991), Paper No. 912366, USA.*
7. *Raheman, H., Phadatare A.G.,* ‘Diesel engine emissions and performance from blends of karanja methyl ester and diese’, *Biomass & Bioenerg,* ***27*** *(2004), 393-397.*
8. *Cenk Sayin, Gumus M,* ‘Impact of compression ratio and injection parameters on the performance and emissions of a DI diesel engine fueled with biodiesel-blended diesel fuel’, *Applied Thermal Engineering,* ***31*** *(2011), 3182-3188.*
9. *Yaliwal V.S., Daboji S. R., Banapurmath N.R., Tewari P. G.,* ‘Production and Utilization of Renewable Liquid Fuel in a Single Cylinder Four Stroke Direct Injection Compression Ignition Engine, *International Journal of Engineering Science and Technology,* ***2*** *(2010), 5938-5948.*
10. *Hariharan V.S., Vijayakumar Reddy K.,* 'Effect of injection pressure on diesel engine performance with Sea lemon oil', *Indian Journal of Science and Technology,* ***4****(8) (2011), 907-909.*
11. *Osama H. Ghazal,* 'Performance and combustion characteristic of CI engine fueled with hydrogen enriched diesel', *International Journal of Hydrogen Energy* ***38****(2013), 15469-15476.*
12. *Kyunghyun Ryu,* 'Effects of pilot injection pressure on the combustion and emissions characteristics in a diesel engine using biodiesel–CNG dual fuel', *Energy Conversion and Management-* ***76*** *(2013), 506–516.*