Available online at www.elixirpublishers.com (Elixir International Journal)

Mechanical Engineering

Elixir Mech. Engg. 81 (2015) 31873-31877

ISSN: 2229-712X

Effect of CI Engine Operating Temperature on Emissions Fuelled With Diesel and Biodiesel Blends

Karsoliya R.P and Mandloi R.K

Department of Mechanical Engineering, M. A. National Institute of Technology, Bhopal, India 462051.

ARTICLE INFO

Article history:

Received: 25 January 2015;

Received in revised form: 28 March 2015;

Accepted: 16 April 2015;

Keywords

CI engine,

Jatropha biodiesel,

Optimum operating temperature,

Exhaust emissions.

ABSTRACT

The aim of the present study is to investigate the optimum operating temperature of a compression ignition (CI) engine that will operate with the minimum level of exhaust emissions. The blends of jatropha with diesel in varying proportions (B10, B20 and B40) are prepared and are investigated in CI engine test rig. The result of engine emissions like CO_2, CO, HC and NOx of pure diesel and biodiesel and their blends are shown by various graphical representations with respect to the engine coolant temperature at different engine loads. From the present study, it can be inferred that it is preferable to operate the engine at temperature 65˚C-80˚C.

Introduction

The automobile has become an integral part of this world, to the extent that in many areas it is nearly impossible to access many services without an automobile. This has a number of negative impacts upon the people and the environment. Pollution from motor vehicle exhaust has public health and environmental consequences. Therefore the fuels used in road transportation are subject to increasingly stringent regulations (EN-590 in Europe [1], ASTM D 975 in USA [2]).

In order to cope with these vital problems biodiesel has lately received more attention because of its enormous resources in the world and environmental friendly characteristics [3]. Biodiesel is defined as fatty acid methyl or ethyl esters from animal fats or vegetable oils [4]. Biofuels are gained from renewable energy resources and it has been proven that they are non-polluting [5].

Many experiments have been done on biodiesel and its blends to evaluate the emissions level like carbon monoxide (CO), carbon dioxide (CO_2), particulate matter, sulphur oxides (SO_2), oxides of nitrogen (NOx) and smoke. V. Subbaiah et al. [6] investigated the performance and emission characteristics on a single cylinder diesel engine of conventional diesel, rice bran oil biodiesel, diesel and biodiesel blend and diesel-biodiesel-ethanol blends. The CO and hydrocarbon emissions (HC) of the biodiesel and all the other fuel blends were lower than that of the diesel fuel. The NOx emissions of the biodiesel and all the other fuel blends were low at lower loads and high at higher loads compared with the diesel fuel.

Raheman and Phadatare [7] observed high CO emissions reduction of around 73–94% with karanja methyl ester (B100) and its mixtures (B80, B60, B40 and B20) in comparison to diesel. Also Ozsezen et al. [8] have noticed that the range of CO emissions reduction was 86.89% and 72.68% for waste (frying) palm oil methyl ester. Munoz et al [9] also found that with the biodiesel mixtures the concentration of carbon monoxide (CO) in the exhaust decreased, except at high speed and load, while HC emissions reduced at low loads, and NOx emissions depended on the speed and load of the engine. Roy [10] examined the emission of carbon monoxide (CO), hydrocarbon (HC), nitric oxide (NO), nitrogen dioxide (NO2), nitrogen oxides (NOx) and carbon dioxide (CO2) with pure and used canola biodiesel blends. CO and HC emissions from biodiesel–diesel blends were obtained significantly less than neat diesel fuel.

In the present scenario the designs of CI engine cooling systems being used in automotives by various manufacturers are not properly suitable to our climate condition. Looking in to the vast varying temperature range of a country it is very difficult to say that which temperature is most suited to operating condition of engines. Mandloi and Rehman [11] investigated the engine performance parameters and exhaust emission using gasoline and liquefied petroleum gas (LPG) as fuel with varying engine temperature, engine speed and engine load on SI water cooled engine test rig connected to eddy current type dynamometer.

Yilmaz [12] carried out experiments on CI engine running on biodiesel-methanol and biodiesel–ethanol blends at ambient (30˚C) and preheated (85˚C) intake air temperatures. Results showed that intake air temperature was one of the primary solutions to reduce HC and CO emissions as compared to ambient conditions.

A lot of work has been done on the study of performance and emission characteristics of alternate fuels in IC engines. Limited amount of work is done related with temperature effect on IC engines. As per the author's point of view, it has been observed that no literature is available for the effect on emissions of biodiesel with the engine operating temperature related to ambient atmospheric temperatures. The authors are in strongopinion to evaluate the research on engine operating temperature with biodiesel and its blends as this would have definite impact on engine performance. The engine temperature is maintained by transfer of heat to a circulating coolant.

Engine Test Set Up And Methodology

A computerized C I engine test rig used for present experimental investigation. This experimental test rig consists of a single cylinder, four strokes, constant speed; direct injection diesel engine is used for the experiments having a rated power output of 5.2 kW at a constant speed of 1500 rpm. The test rig also have eddy current dynamometer as loading system, water

Tele:

E-mail addresses: manitkarsoliya@gmail.com

cooling system, lubrication system and various sensors and instrumentation integrated with computerized data acquisition system for online measurement of load, air & fuel flow rate, instantaneous cylinder pressure, position of crank angle, exhaust emissions and smoke opacity etc. Figure 1 shows the photographic image of the experimental setup used in the laboratory to conduct the present study and Fig. 2 shows the schematic representation of the experimental test setup.

Commercially available lab-view based engine performance analysis software "Enginesoft" is used for on line performance data storage. The emission measurement system is used to measure the constituents of exhaust gas. This system consists of an exhaust gas analyzer (Fig. 3) that measures the exhaust gas constituents of Carbon dioxide (CO_2), Carbon monoxide (CO), Oxides of nitrogen (NOx) and Unburnt Hydrocarbons (HC).

Cylinder Heat Transfer Measurements

There are a wide range of temperature and heat fluxes in an internal combustion engine. The values of local transient heat fluxes can vary by an order of magnitude depending on the spatial location in the combustion chamber and the crank angle. The source of the heat flux is not only the hot combustion gases, but also the engine friction that occurs between the piston rings and the cylinder wall. When an engine is running at steady state, the heat transfer throughout most of the engine structure is steady.

The maximum heat flux through the engine components occurs at fully open throttle and at maximum speed. Peak heat fluxes are in order of 1to10 $MW/m.^2$ the heat flux increase with

Figure 1. Experimental setup

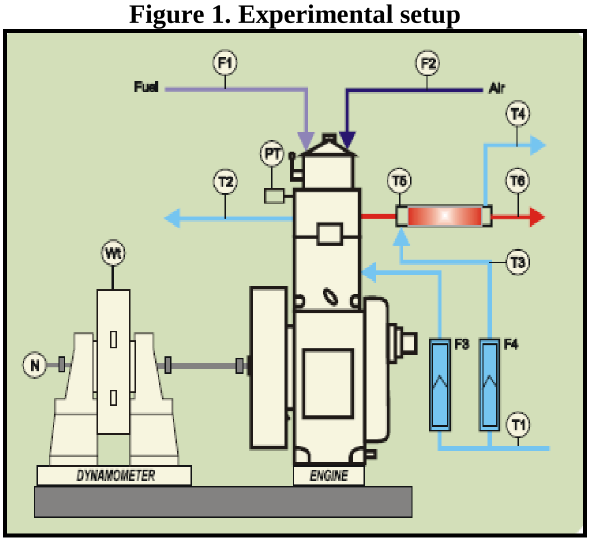

Figure 2. Schematic representation of set up

in increases with increasing engine load and speed. The heat flux is largest in the centre of the cylinder head, the exhaust valve seat and the centre of the piston. About 50% of the heat flow to the engine coolant is through the engine head and valve seats, 30% through the cylinder sleeve or walls and remaining 20% through the exhaust port area

Effect of Engine Temperature

Temperature control is very important for combustion engines as temperature is a critical; factor both for chemical reactions and mechanical stresses. Traditionally, temperature control is performed by feedback of a global quantity, the coolant temperature, which however is a poor indicator of specific temperatures. The use of pumps opens flew possibilities for thermal control, in particular in terms of efficiency, but also of pollution, especially in the cold start phase. It shows that predictive control and the use of coolant pumps allow to regulating specific temperatures [13].

Figure 3. Exhaust Gas Analyzer

Heat Release and Component Temperature in CI Engines

The heat flux to the combustion chamber walls varies with engine design and operating condition. Also the heat flux to the various parts of the combustion chamber is not the same. As a result of this nonuniform heat flux and the different thermal impedances between locations on the combustion chamber surface and the cooling fluid, the temperature distribution within engine components is nonuniform [13].

Effect of Engine Variables

The following variables affect the magnitude of the heat flux to the different surfaces of the engine combustion chamber and the temperature distribution in the components that comprise the chamber, engine speed, engine load, overall equivalence ratio, compression ratio, injection timing, swirl motion, wall material, mixture inlet temperature, coolant temperature and composition. These variables with speed and load have the greatest effect [13].

Engine Cooling Systems

There are two types of engine cooling systems used for heat transfer from the engine block and head; liquid cooling and air cooling. With a liquid coolant, the heat is removed through the use of internal cooling channels with in the engine block. Liquid systems are much quieter than air systems, since the cooling channel absorbs the sounds from the combustion process. However, in this experimentation the engine temperature was artificially maintained by controlling the flow rate of coolant to the required fixed temperature.

Results and Discussion

The emission parameters considered in the present study are CO_2, CO, NOx and HC responding to coolant temperatures considered as engine operating temperature. Exhaust emission evaluation is carried out in following three different experimental stages;

1. Diesel as fuel at different coolant temperatures and loads.
2. Jatropha bio-diesel as fuel at different coolant temperatures and loads.
3. Blends of jatropha biodiesel and diesel as fuel at different coolant temperatures and loads.

The blend proportions used to conduct the experiments are B10, B20 and B40.

The blends are prepared by direct mixing of both the fuels in required proportions. Mixing is done with the help of a magnetic mixer. Blends used are as follows;

- B10: 10% biodiesel and 90% diesel
- B20: 20% biodiesel and 80% diesel
- B40: 40% biodiesel and 60% diesel

Figure 4 presents the variation of CO with engine coolant temperature for biodiesel and its blends with diesel at part load. It can be observed that CO emission decreases with increase in temperature till 60°C. The trend may be due to better combustion of fuel at high temperature inside the cylinder. It can also be observed that at temperatures beyond 80°C CO emissions increases which again shows combustion is not proper at very high operating temperatures. Also lower CO emissions for biodiesel and its blends as compared to diesel may be due to the oxygenated nature of biodiesel due to which more of carbon gets oxygenated forming CO_2. Figure 5 presents the variation of CO_2 with engine coolant.

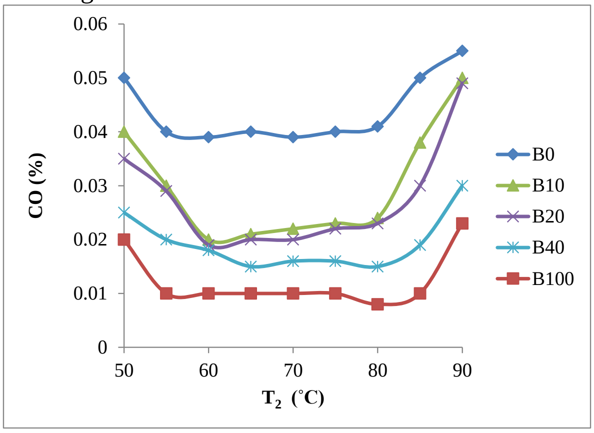

Figure 4. CO emissions from B0, B10, B20, B40 and B100 with different coolant temperatures (T2) at part load

Temperature for biodiesel and its blends with diesel at part load. The amount of CO_2 in the exhaust is an indication of degree of complete oxidation of the carbon constituent of the fuel and hence indicates the extent of conversion of chemical energy into thermal energy. It is observed from the figure that CO_2 emission initially decrease, reach the lowest and subsequently increase with the increase in coolant temperature for all the fuels tested. It is also observed that CO_2 emission is higher for biodiesel compared to diesel at all temperatures. The trend may be due to complete oxidation of carbon present in the biodiesel due to its inherent oxygen content.

The variation of HC with coolant temperature for biodiesel and its blends with diesel at part load is shown in Fig. 6. The unburnt hydrocarbons (HC) are generated in the exhaust as the result of incomplete combustion of fuel. Hydrocarbons cause eye irritation and choking sensations. They are major contributors to the characteristic diesel exhaust smell and also have a negative environmental effect, being an important component of smog. Hydrocarbon from diesel engines come primarily from (i) the fuel trapped in the injector at the injection that later diffuses out, (ii) the fuel mixed into the air surrounding the burning spray so lean that it cannot burn, (iii) the fuel trapped along the walls by crevices, deposits, or oil due to impingement by the spray.

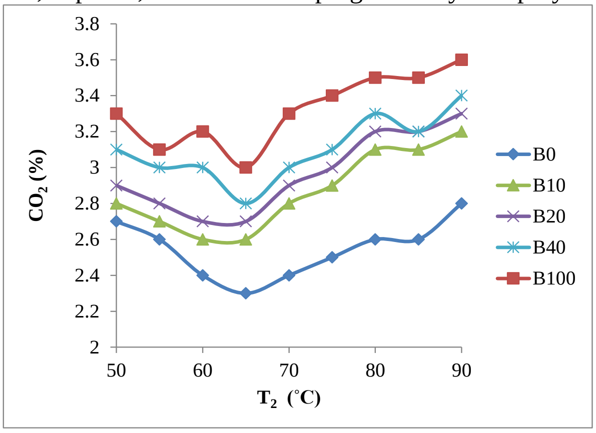

Figure 5. CO_2 emissions from B0, B10, B20, B40 and B100 with different coolant temperatures (T_2) at part load

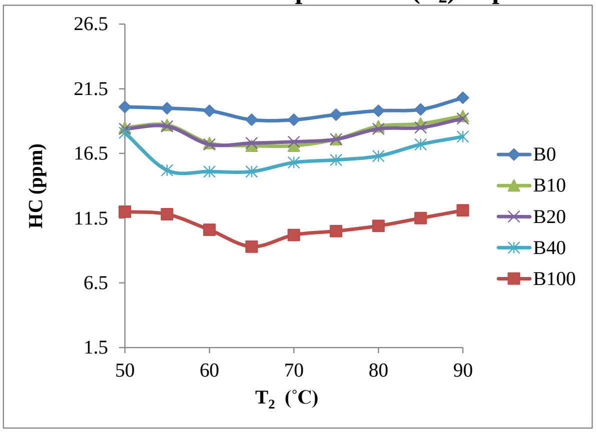

Figure 6. HC emissions from B0, B10, B20, B40 and B100 with different coolant temperatures (T_2) at part load

It can be observed from the figure that HC emissions decrease with increase in temperature for all the fuels tested. The trend observed may be due to complete combustion of fuel at higher temperatures. It is also observed that HC decreases with the increase in blend proportion. The trend may be due to better combustion of biodiesel due to its oxygenated nature.

Figure 7 shows comparison of variation of NOx with engine coolant temperature for biodiesel and its blends with diesel at part load. Nitrogen oxides are formed throughout the combustion chamber during the combustion process due to the reaction of atomic oxygen and nitrogen. Reactions forming NOx are very temperature dependent and NOx emissions from the engine are low at lesser loads.

It can be observed from the figure that NOx emissions increases for biodiesel and its blends while it decreases for diesel with increase in coolant temperature. The lower NOx emission for biodiesel and its blends at lower temperature is because less oxygen is available from blends to form NOx due to less heat. At higher temperature availability of oxygen for biodiesel and higher heat increases the formation of NOx.

Figure 8 presents the variation of CO with engine coolant temperature for biodiesel and its blends with diesel at full load. It can be observed that CO emission decreases with increase in temperature. It is also observed that CO emissions increase with the increase in load. The trend can be attributed to more fuel being consumed at higher loads which means rich running of the engine and there being insufficient oxygen to convert all the carbon in the fuel to carbon dioxide. Also lower CO emissions for biodiesel and its blends as compared to diesel may be due to the oxygenated nature of biodiesel due to which more of carbon gets oxygenated forming CO_2.

Figure 9 presents the comparison of variation of HC with engine coolant temperature for biodiesel and its blends with diesel at full load. It can be observed that HC emissions increase with increase in load for all the fuels tested. The increase at higher loads may be due to the rich fuel air mixture as compared to stoichiometric which leads to improper burning thereby resulting in increase of HC content in the exhaust. It can be observed that HC emissions decrease with increase in blend proportion. The trend can be attributed to the higher oxygen content of biodiesel due to which complete combustion takes place inside the cylinder.

Figure 10 presents the variation of NOx with engine coolant temperature for biodiesel and its blends with diesel at full load. It can be observed that NOx emissions increase with increase in load.

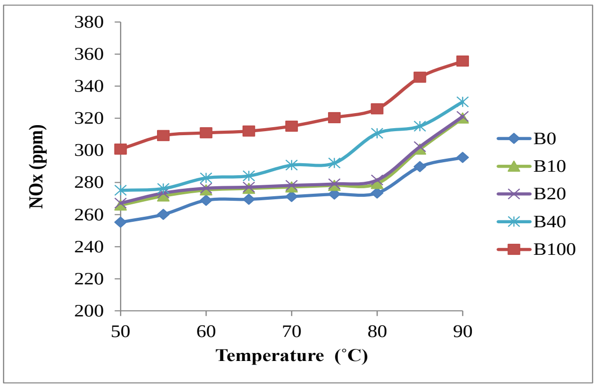

Figure 7. NOx emissions from B0, B10, B20, B40 and B100 with different coolant temperatures (T_2) at part load

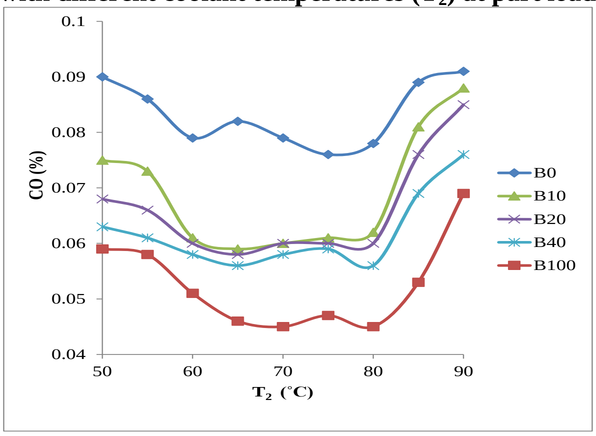

Figure 8. CO emissions from B0, B10, B20, B40 and B100 with different coolant temperatures (T_2) at full load

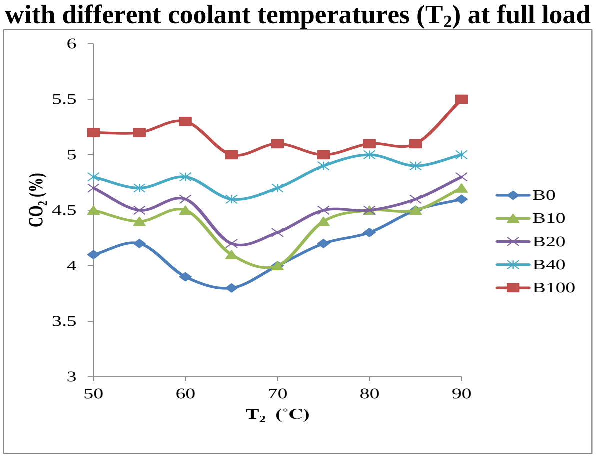

Figure 9. CO_2 emissions from B0, B10, B20, B40 and B100 with different coolant temperatures (T_2) at full load

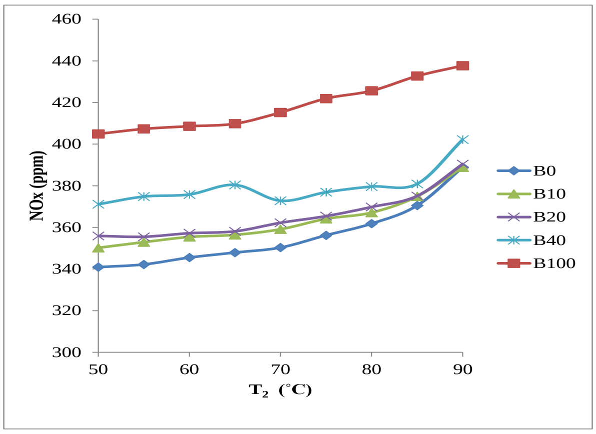

Figure 10. NOx emissions from B0, B10, B20, B40 and B100 with different coolant temperatures (T_2) at full load

The trend can be attributed to more temperature with diesel as fuel and higher temperature and inherent higher oxygen content with biodiesel and its blends as fuels.

It can be observed that the NOx emissions are higher for biodiesel blends at higher temperatures. The reason for higher NOx is higher oxygen content of biodiesel than diesel. During combustion process of blends, more oxygen is available from fuel and nitrogen from air readily gets combined with oxygen at higher cylinder temperatures and forms compounds.

Conclusions

The experimental study is conducted on a single cylinder, four stroke, constant speed, water-cooled, direct injection diesel engine using jatropha biodiesel and its blends with diesel. The thermal performance and smoke characteristics were evaluated by running the engine at different combinations of preset engine loads, ranging part to full load, with various coolant temperatures at exit from 50˚C to 90˚C in steps of 10˚C. From the experimental investigation on CI engine following conclusions can be drawn;

1. Based on the observation of graphs of CO versus coolant temperature, it can be concluded that CO emission decreases with increase in temperature due to better combustion of fuel at high temperature inside the cylinder. However, beyond 80˚C CO emissions again increase.
2. Lower CO emissions for biodiesel and its blends as compared to diesel may be due to the oxygenated nature of biodiesel due to which more of carbon gets oxygenated forming CO_2.
3. It is also observed that CO emissions increase with the increase in load attributed to more fuel being consumed at higher loads which means rich running of the engine and there being insufficient oxygen to convert all the carbon in the fuel to carbon dioxide
4. Based on the observation of graphs of CO_2 versus coolant temperature, it can be concluded that CO_2 emission initially decrease, reach the lowest and subsequently increase with the increase in coolant temperature for all the fuels tested.
5. CO_2 emission is higher for biodiesel compared to diesel at all temperatures. The trend may be due to complete oxidation of carbon present in the biodiesel due to its inherent oxygen content.
6. It can be observed that CO_2 increases with the increase in load. The trend observed may be because of more fuel being burnt at higher loads due to which more carbon is available to form CO_2.
7. Based on the observation of graphs of HC versus coolant temperature, it can be concluded that HC emissions decrease with increase in temperature for all the fuels tested. The trend observed may be due to complete combustion of fuel at higher

temperatures. However, at higher temperatures HC emissions again increase.

8. It is also observed that HC decreases with the increase in blend proportion. The trend may be due to better combustion of biodiesel due to its oxygenated nature.

9. It can be observed that HC emissions increase with increase in load for all the fuels tested. The increase at higher loads may be due to the rich fuel air mixture as compared to stoichiometric which leads to improper burning thereby resulting in increase of HC content in the exhaust.

10. Based on the observation of graphs of NOx versus coolant temperature, it can be concluded that NOx emissions increases for biodiesel and its blends while it decreases for diesel with increase in coolant temperature. The lower NOx emission for biodiesel and its blends at lower temperature is because less oxygen is available from blends to form NOx due to less heat. At higher temperature availability of oxygen for biodiesel and higher heat increases the formation of NOx.

11. It can also be observed that NOx emissions increase with increase in load. Based upon the emission characteristics of CI engine under investigation it is inferred that temperature 65˚C-80˚C is the optimum temperature range for the engine. The experimental result shows that there is a requirement to think about changes in existing Engine Cooling System Design as per India's climatic condition.

References

[1] UNE EN-590:2004. Automotive fuels—diesel—requirements and test methods.

[2] ASTM D 975-06. Standard specification for diesel fuel oils.

[3] B.S. Ameer, K.R. Gopal and S.,Jebaraj, "A review on biodiesel production, combustion, emissions and performance," Renewable and Sustainable Energy Reviews, vol. 13, pp. 1628–1634, 2009.

[4] A. Demirbas, "Progress and recent trends in biofuels," Progress in Energy and Combustion Science, vol. 33(1), pp. 1–18, 2007.

[5] M.F. Demirbas, M. Balat and H.Balat, "Potential contribution of biomass to the sustainable energy development," Energy Conversion and Management, vol. 50, pp. 1746–1760, 2009.

[6] G. V. Subbaiah, K. R. Gopal, S. A. Hussain, B. D. Prasad and K. T. Reddy, "Rice bran oil biodiesel as an additive in diesel- ethanol blends for diesel engines," IJRRAS, vol. 3(3), pp. 334-342, June 2010.

[7] H. Raheman and A.G. Phadatare, "Diesel Engine Emissions and Performance from Blends of Karanja Methyl Ester and Diesel," Biomass Bioenergy, vol. 27, pp. 393-397, 2004.

[8] A.N. Ozsezen, M. Canakci, A. Turkcan and C. Sayin, "Performance and combustion characteristics of a DI diesel engine fueled with waste palm oil and canola oil methyl esters," Fuel, vol. 88, pp. 629–636, 2009.

[9] M. Munoz, F. Moreno and J. Morea, "Emissions of an automobile diesel engine fueled with sunflower methyl ester," Transactions of the ASAE, vol. 47(1), pp. 5-11, 2004.

[10] M.M. Roy, "Biodiesel production and comparison of emissions of a DI diesel engine fueled by biodiesel–diesel and canola oil–diesel blends at high idling operations," Applied Energy, vol. 106, pp. 198–208, 2013.

[11] R. K. Mandloi and A. Rehman, "Engine performance characteristics under controlled engine temperature with variable operating parameters," Proc. Of ASME/JSME 2011 8th Thermal Engineering Joint Conference, Honolulu, Hawaii, USA, March 13-17, 2011.

[12] N. Yilmaz, "Performance and emission characteristics of a diesel engine fuelled with biodiesel–ethanol and biodiesel–methanol blends at elevated air temperatures," Fuel, vol. 94, 440–443, 2012.

[13] J.B. Heywood, Internal Combustion Engine Fundamentals, McGraw-Hill, 1988.