PERFORMANCE AND EMISSION ANALYSIS OF A DIESEL ENGINE FUELLED WITH JATROPHA AND COTTON SEED BIODIESELS

Raghuram Pradhan[1], **Sukumar Puhan** [2], **M. Sreenivasan** [3]
1, 2 & 3 (Professor, Department of Mechanical Engineering, Pace IT&S, A.P, India)
Corresponding Author: Raghuram Pradhan

ABSTRACT
Biodiesel is a non-toxic, biodegradable and renewable alternative fuel that can be used in diesel engines with little or no modification. It usually produces less air- pollutants than petroleum-based diesel.Biodiesel is a fatty acid alkyl ester, which can be derived from any vegetable oil by trans esterification(alcoholysis).The main objective of this paper is to investigate the suitability of biodiesel and its blends as a fuel for diesel engines and to estimate the engine performance and emission. Also the results were compared to find out the suitable blends of biodiesel with diesel for better performance and low emissions. The neat fuels and their blends with diesel fuel were studied at steady-state engine operating conditions in a single-cylinder diesel engine. It was proposed and considered the best in order to understand the effect of the biodiesel on the engine performance various parameters like mechanical efficiency, brake thermal efficiency, indicated thermal efficiency, brake specific fuel consumption for analysis. Also it was proposed to do exhaust gas analysis for oxides of-nitrogen (NOx), HC, CO and particulate matter (PM) from the diesel engine for the selected biodiesels and their blends.

Keywords:*Biodiesel, Transesterification,Ginning,Diesel Engine(4S),MEOC,MEOJ,Performance and Emission etc..*

1. INTRODUCTION

The alternative fuels are the renewable sources of energy and these fuels can be derived from different resources other than petroleum. There are several alternative fuels like biodiesel, ethanol, natural gas, propane etc. For the automotive engines the biodiesel plays a significant role as alternative fuel. It is also important to explore the feasibility of substitution of diesel with an alternative fuel that can be produced within the country on a massive scale for commercial utilization. The potential alternative fuels are Alcohols (Methanol and Ethanol), Liquefied Petroleum Gas (LPG), Compressed Natural Gas (CNG), Hydrogen andVegetable oils. Liquid biofuel have been used since the early days of the car industry. The prime liquid alternative fuels are alcohols and vegetable oils. Both alcohols and vegetable oils are derived from renewable biomass sources. Alcohols due to their low cetane number are not suitable for direct use in diesel engines. The poor volatility and low octane number make vegetable oils unsuitable for spark ignition engines.

Vegetable oil based fuels are biodegradable, non-toxic and significantly reduce pollution. They offer the advantage of being able to be readily used in existing diesel engines without modifications as their properties can be brought closer to diesel. They have a reasonably high cetane number. The carbon residue of vegetable oils is higher than that of diesel, which leads to a smoky exhaust in a diesel engine. Vegetable oils do not add any extra carbon dioxide gas to the atmosphere, as opposed to fossil fuels, which are causing changes in the atmosphere. An overview of the important research work done previously is presented here. It was observed from the literature review that thermodynamic tests, based on engine performance evaluation have established the feasibility of using a variety of alternative fuels in internal combustion engines. A greater part of the literature covers several aspects of water cooled engines [32, 33] while it was very little for air cooled engines [25]. In Indian context, biodiesel developed from non-edible and edible oil seeds can be used in diesel engines. Some of the notable works on biodiesel derived from various sources were done by Avinash Kumar Agarwal [15],Sahoo P.K.et al. [30], Nagarajan G. et al. [31], Banapurmath N.R et. Al[9], Carraretto A et al. [29], Deepak Agarwal et al.[13], Puhan S. et al.[5], Pramanik K. [3], to study the performance, combustion and emission characteristics of a diesel engine running on biodiesel. But still the technology is yet to be fully exploited.

W.G. Wang et al [2000]carried out a comparative study on the performance and exhaust emissions from in-use heavy trucks fuelled with a biodiesel blend with those from trucks fuelled with petroleum diesel. The biodiesel blend tested is a mixture of 35% biodiesel and 65% petroleum diesel, a blend designated as B35. The emission test results have shown that the heavy trucks fuelled by B35 emitted significantly lower particulate matter (PM), moderately lower carbon monoxide (CO) and hydrocarbon (HC) than the same trucks fuelled by diesel (D2). Oxides of nitrogen (NOx) emissions from B35 and D2, however, were generally in the same level.M.A. Kalamet al [2002] investigated the effect of palm oil methyl ester to evaluate the performance, emissions and wear characteristics of an Isuzu IDI diesel engine in Malaysia, when the ambient environmental temperature was 25ºC to 35◦C. They were reported that the cetane number of palm oil methyl ester is 50–52 which is slightly lower than that of conventional diesel, but within an acceptable range. K. Pramaniket al (2003) investigated the effects of blends of varying proportions of Jatrophacurcas oil and diesel on a CI engine. The blends were prepared, analyzed and compared with diesel fuel for its performance and emission characteristics. The investigation was carried out to reduce the viscosity of Jatrophacurcas oil close to that of conventional fuel to make it suitable for use in a C.I. engine and to evaluate the performance of the engine with the modified oils.SukumarPuhan et al [2005] prepared Mahua oil methyl ester by transesterification process. Blends of methyl esters of mahua and diesel were tested in a four-stroke diesel engine. They were reported that the brake thermal efficiency increased marginally in the Mahua oil ethyl esters and CO, HC, NOx emissions and smoke density reduced marginally.Shashikant Vilas Ghadge et al2005] were developed a technique to produce biodiesel from Mahua oil (Madhucaindica) having high free fatty acids (19% FFA). A two-step pretreatment was followed to reduce the high FFA level of Mahua oil to less then 1%. Each step was carried out with 0.30-0.35 v/v methanol-to-oil ratios in the presence of 1% v/v H_2SO_4 as an acid catalyst in 1-hour reaction at 60°C. The mixture was allowed to settle for an hour after the reaction, and methanol-water mixture that separated at the top layer was removed. The second step product at the bottom was transesterified using 0.25 v/v methanol and 0.7% W/v KOH as alkaline catalyst to produce biodiesel. The properties of biodiesel thus produced could be compared using American and European standards.B.K. Barnwal et al [2005] attempted to review the works done on various aspects of biodiesel such as production and utilization, resources available, process developed performance in existing engines, environmental considerations, the economic aspect, and barriers to the use of biodiesel. It has been found that thin neat vegetable oils can be used as diesel fuels in conventional diesel engines, but this leads to a number of problems related to the type and grade of oil and local climate conditions. The injection, atomization and combustion characteristics of vegetable oil in diesel engines are significantly different from those of diesel.M. Pugazhvadivu et al [2005] carried out experimental investigation in a diesel engine using waste frying oil as fuel. The properties such as viscosity, density, calorific value, and flash point were analyzed by them. The performance and emission characteristics of the diesel engine were evaluated with and without preheating of the fuel. The results indicated that preheating the fuel reduced the viscosity of waste frying oil. It was concluded that engine performance was improved and CO and smoke emissions got reduced.A.S. Ramadhas et al [2005] were studied the performance and emission characteristics of diesel engine fuelled with rubber seed oil. They were reported that the lower blends of biodiesel increased the brake thermal efficiency and reduced the exhaust gas emission compared to higher concentration of rubber seed oil in the blends.Md. NurunNabi et al [2005] investigated the combustion characteristics and exhaust emission with neat diesel and blends of neem biodiesel. They studied the infrared spectra for esterified and non-esterified oil. The IR-spectra of neat esterified and non-esterified Neem oil show the functional groups, which indicate the presence of alkanes and lesser extent of aromatic and poly-aromatic groups, with a clear absence of phosphorus and sulphur. The IR-spectra of the esterified Neem oil also showed the presence of significant amount of esters. The esterified Neemoil contains a little amount of water and this water was removed by heating before use in the engine. They concluded that exhaust emissions, smoke and CO were reduced, while the NOx emission increased marginally.J. Patterson et al [2006] carried out experimental investigation on diesel engine using three different vegetable oils (Rape, Soya and Waste oil). They also studied the physical properties of biodiesel and compared it with mineral diesel. A blend of 5% by volume of biodiesel does not affect any performance and emission characteristics. Further, studies were conducted on the combustion characteristics and they concluded that ignition delay is longer with biodiesel than with diesel.Octavio Arms et al [2006] focused on measurement and analysis of smoke from diesel engine fuelled with conventional fuel and biodiesel. In this investigation transient processes were studied at engine start, constant speed and constant load. They concluded the presence of oxygen molecular content and the absence of aromatic and sulphur compounds in the biodiesel led to an improvement in the local fuel/oxygen ratio during combustion. They have reported that the difficulties in the fuel atomization (higher viscosity compared to conventional fuel) and evaporation (higher initial boiling point compared to conventional fuel) at the relative low starting temperatures have increased the smoke opacity.Deepak Agarwal et al [2006] studied the control of NOx emission in biofuel run diesel engine and the effects of Exhaust gas recirculation(EGR). Research was shown that biodiesel-fuelled engine produces less CO, HC and particulate matter emissions but higher NOx when compared to mineral diesel fuel. EGR is effective to reduce NOx from diesel engine because it lowers the flame temperature and the oxygen concentration in the combustion chamber.C.D. Rakopouls et al [2006]made a detailed study to evaluate and compare the use of two blend ratios of biodiesel 10:1 and 20:80 in a direct injection diesel engine. The results indicated that the smoke density was significantly reduced with the use of bio-diesel blends of various origins with respect to that of the neat diesel. This was dominant with the high percentage of bio-diesel in the blend. The NOx emissions were slightly reduced with the use of bio-diesel or vegetable oil blends. It was observed that the engine performance with the bio-diesel and the vegetable oil blends of various origins was similar to that of the neat diesel fuel with nearly the same brake thermal efficiency, showing higher specific fuel consumption for the high load and a minimum of it at the 10:90 blends for the medium load.Md. NurunNabi et al [2006]investigated the combustion and exhaust gas emission characteristics when the engine was fuelled with blends of methyl esters of Neem oil and diesel. The optimum blend of biodiesel and diesel fuel, based on the trade-off of particulate matter decrease and NOx increase, was a 20/80 biodiesel/diesel fuel blend. After an injection (BOI) delay of 3º NOx emissions reduced while maintaining emission reductions associated with fuelling a diesel engine with a 20/80 biodiesel/diesel fuel blend. The retarded timing reduced the time for combustion to occur in the cylinder, reducing the peak pressures and temperatures that enhance the formation of NOxemissions.Mustafa Canakcia et al [2006] were investigated the applicability of Artificial Neural Networks (ANNs) for the performance and exhaust-emission values of a diesel engine fuelled with biodiesels from different feeds stocks and petroleum diesel fuels. Experimental results on the engine performance and emissions characteristics of two different petroleum diesel-fuels (No. 1 and No. 2), biodiesels (from soybean oil and yellow grease), and their 20%blends with No. 2 diesel fuel were used for the study. The performance and exhaust emissions from a diesel engine, using biodiesel blends with No. 2 diesel fuel up to 20%, have been predicted using the ANN model. The actual and predicted values of SFC, CO, CO_2, HC, O_2 and NOx were compared. It was reported that the network has yielded R^2 values of 0.99 and the mean percentage errors are smaller than 4.2 for the training data, while the R^2 values are about 0.99 and the mean percentage errors are smaller than 5.5 for the test data.DeepakAgarwal et al (2006),Combustion and exhaust emissions with neat diesel fuel and diesel–biodiesel blends have been investigated in a four stroke naturally aspirated (NA) direct injection (DI) diesel engine and Compared with conventional diesel fuel. Methyl ester of non-edible neem oil was prepared with lye catalyst and methanol and compared with conventional diesel fuel. Diesel exhaust emissions including smoke and CO were reduced, while NOx emission was increased with diesel-NOME (Neem Oil Methyl Ester) blends. The reductions in CO and smoke emissions and the increase in NOx emission with diesel-NOME blends were associated with the oxygen content in the fuel. Compared with usual diesel fuel, the computed result shows lower NOxemission with NOME.Cherng-Yuan Lin et.al [2007] employed pre-oxidation process to produce biodiesel. In this investigation of four types of diesel, biodiesel with and without an additional pre-oxidation process, a commercial biodiesel and ASTM No.2D diesel were compared for their fuel properties, engine performance and emission characteristics. The experimental results have shown increase in fuel consumption, brake thermal efficiency, equivalence ratio and exhaust gas temperature. The results indicate decrease of CO_2, CO and NOx emissions. Finally they concluded that pre-oxidation process effectively improves the fuel properties and reduces the emissions.Avinash Kumar Agarwal [2007] carried out a detailed experimental study on the applicability of biofuels for internal combustion engines. It was reported that all the tests for characterization of biodiesel demonstrated that almost all the important properties of biodiesel are in very close agreement with the mineral diesel making it a potential candidate for the application in CI engines. A 20% blend of biodiesel with mineral diesel improved the cetane number of diesel. The calorific value of biodiesel was found to be slightly lower than mineral diesel. The 20% biodiesel blend was found to be the optimum concentration for biodiesel blend, which improved the peak thermal efficiency of the engine by 2.5%, reduced the exhaust emissions and the brake specific energy consumption substantially. H. Raheman et al [2007] investigated the performance of biodiesel obtained from mahua oil and its blend with high speed diesel in a Ricardo E6 engine. Using a two step 'acid–base' process; acid-pre treatment followed by main base-transesterification reaction, using methanol as reagent and H_2SO_4 and KOH as catalysts for acid and base reactions, respectively, was followed by them to produce biodiesel from crude mahua oil in a laboratory scale processor. They have reported that the properties of the fuels thus produced were found to be comparable to diesel and confirming to both the American and European standards. Studies on engine performance and emissions (CO, smoke density and NOx) were made to evaluate and compute the behaviour of the diesel engine running on biodiesel. It was found that the mean BSFC for the blends was higher than that of pure HSD by 4.3%, 18.6%, 19.6%, 31.7% and 41.4%, respectively, for every 20% additional blending of biodiesel in diesel. AliKeskinet al [2008] studied the usability of cotton oil soapstock biodiesel–diesel fuel blends as an alternative fuel for diesel engines. They have produced the biodiesel by reacting cotton oil soapstock with methyl alcohol at determined optimum condition. The cotton oil biodiesel–diesel fuel blends were tested in a single cylinder direct injection diesel engine. Engine performances and smoke values at full load condition were studied by them. They concluded that torque and power output of the engine with cotton oil soapstock biodiesel–diesel fuel blends decreased by 5.8% and 6.2%, respectively. Specific fuel consumption of engine with cotton oil soapstock–diesel fuel blends increased up to 10.5%. At maximum torque speeds, smoke level of engine with blend fuels decreased up to 46.6%, depending on the amount of biodiesel. These results were compared with diesel fuel values. Particulate material emission of the engine with blend fuels at maximum torque speed decreased by 46.6%.Anand et al [2008] investigated the effect of injecting the blends of Jatropha and diesel fuel at 200 bar and 250 bar on the performance and emission characteristics of a single cylinder diesel engine. It was concluded that brake thermal efficiency of the blends are lower than diesel due to longer ignition delay of the esters even at 250 bar. An increase in the smoke level was reported at 200 bar. However NO_X emissions are reported to be lower due to lower exhaust gas temperatures.Banapurmath et al [2008] investigated the performance and emission characteristics of a diesel engine operating with methyl esters of sesame, Honge and Jatropha oil. Comparative measures of brake thermal efficiency, smoke opacity, HC, CO, NO_X, ignition delay, combustion duration and heat release rates have been discussed. Engine performance in terms of higher brake thermal efficiency and lower emissions (HC, CO, NO_X) with sesame oil methyl ester operation was observed compared to methyl esters of Honge and Jatropha oil operation. The brake thermal efficiency with Honge, Sesame and Jatropha oil methyl esters are 29.51%, 30.4% and 29%, respectively, at 80% load and 31.25% with diesel. It was also reported that all the esters resulted in slightly higher smoke emissions than diesel, and it an increased ignition delay and combustion duration as compared to neat diesel.Breda keg [2008] investigated the influence of neat biodiesel from rape seed oil on the injection, spray, and engine characteristics to reduce harmful emissions in a bus diesel engine. Engine characteristics are determined experimentally under 13 mode ESC test conditions. It was concluded from the results that, by using biodiesel, harmful emissions (NOx, CO, smoke and HC) can be reduced to some extent by adjusting the injection pump timing properly.Ejaz M et al [2008] presented a detailed review of the use of biodiesel fuel for compression ignition engines. The study was based on the reports of about 50 scientists including (some manufacturers and agencies) who published their results between 1900 and 2005. The raw biodiesel showed injector coking and piston ring sticking. However transesterification decreased the viscosity, density and flash point of the fuel. The results obtained, by using such oils in compression ignition engines as fuel, were satisfactory only for short term. A mix of the transesterified biodiesel oil with diesel upto 20% has shown satisfactory results. It was also mentioned that the biodiesel fuel is environment friendly, produces much less NOx and HC and absolutely no SO_X and no increase in CO_2 at global level. It was concluded that there was a slight decrease in brake power and a slight increase in fuel consumption. However, the lubricant properties of the biodiesel are better than diesel, which has led to an increase the engine life.M.K.Ghosal et al [2008]investigated the performance of a compression ignition engine by using mahua methyl ester and its blends with diesel fuel. Short-term engine performance tests were conducted by them using four different blends of mahua methyl ester oil with diesel fuel from 20% to 100% by volume at three fuel temperatures (30ºC, 50 ºC and 70ºC) and at two injection pressures (176 bar and 240 bar). It was reported that the performance of engine with blend fuel (20% mahua methyl ester and 80% diesel) was found to be better than the other blend fuels. But the values of power output, SFC, Brake thermal efficiency and Exhaust gas temperature in case of blend fuel B20 (20% mahua methyl ester and 80% diesel) were observed to be respectively 3% more, 9% more, 12%more and 0.5% less than the diesel fuel at 70ºC temperature and 240 bar pressure.Houfang Lu et al [2009] developed a two-step process consisting of pre-esterification and transesterification to produce biodiesel from crude Jatrophacurcas oil. The free fatty acids (FFAs) in the oil were converted to methyl esters in the pre-esterification step using sulphuric acid or solid acid prepared by calciningmetatitanic acid as catalysts. The acid value of oil was reduced from the initial 14 mg-KOH/g-oil to below1.0 mg-KOH/g-oil in 2 h under the conditions of 12 wt% methanol, 1 wt% H_2SO_4 in oil at 70ºC. The conversion of FFAs was higher than 97% at 90ºC in 2 h using 4 wt% solid acid and a molar ratio of methanol to FFAs of 20:1. Phospholipid compounds were eliminated during pre-esterification and a separate degumming operation was unnecessary. The yield of biodiesel by transesterification was higher than 98% in 20 min using 1.3% KOH as catalyst and a molar ratio of methanol to oil 6:1 at 64ºC**.**Prafulla D et al[2009] compared the production of biodiesel from different edible and non-edible vegetable oils to optimize the biodiesel production process. The analysis of different oil properties, fuel properties and process parameter optimization of non-edible and edible vegetable oils were investigated in detail. A two-step and single-step transesterification process was used to produce biodiesel from high free fatty acid (FFA) non-edible oils and edible vegetable oils, respectively. This process gives yields of about 90–95% for J. curcas, 80–85% for P. glabra, 80–95% for canola, and 85–96% for corn using potassium hydroxide (KOH) as a catalyst. The fuel properties of biodiesel produced were compared with ASTM standards for biodiesel and are found be within the prescribed limits.P.K. Devan et al[2009] carried out experimental investigations for complete replacement of diesel fuel with bio-fuels. For this purpose they have used the bio-fuels, namely, methyl ester of paradise oil and eucalyptus oil blends. Various proportions of paradise oil and eucalyptus oil are prepared on volume basis and used as fuels in a single cylinder, four-stroke DI diesel engine, to study the performance and emission characteristics of these fuels. Methyl ester derived from paradise oil is considered as an ignition improver. The reports show a 49% reduction in smoke, 34.5% reduction in HC emissions and a 37% reduction in CO emissions for the Me50–Eu50 blend with a 2.7% increase in NOx emission at full load. There was a 2.4% increase in brake thermal efficiency for the Me50–Eu50 blend at full load. It was also reported that the combustion characteristics of Me50–Eu50 blend are comparable with those of diesel.**P.K. Devan et al [2009]** investigated experimentally the performance, emission and combustion characteristics of a diesel engine using neat poon oil and its blends of 20%, 40%, and 60%, and standard diesel fuel separately. They have mentioned that the common problems posed when using vegetable oil in a compression ignition engine are poor atomization; carbon deposits, ring sticking, etc. Further they have stated that when blended with diesel, poon oil presented lower viscosity, improved volatility, better combustion and less carbon deposit. It was also observed by them that there was a reduction in NOx emission for neat poon oil and its diesel blends along with a marginal increase in HC and CO emissions. The carbon monoxide (CO) emissions from neat poon oil and its diesel blends were higher except in the case of the 20% blend where it was reduced by 12%. However, there was an increase in CO emission for neat poon oil by 35% at full load. The hydrocarbon (HC) emissions of poon oil and its diesel blends are slightly higher than those of diesel fuel except in the case of the 20% blend. There was an increase in hydrocarbon emission by 18% in the case of neat poon oil whereas 14% reduction was observed in the case of the 20% blend at full load. The smoke emission from 20% blend was lower than that of standard diesel by 3% whereas, increase in smoke emissions was observed for neat poon oil by 15% at full load. The reduction of the NOx emission is 32% for neat poon oil. Brake thermal efficiency was slightly lower for neat poon oil and its diesel blends. It was concluded that the combustion characteristics of poon oil–diesel blends performed better than neat poon oil.Ragit S.S et al [2010]investigated the performance of a four stroke single cylinder water cooled engine using neem ester and its blends with diesel fuel. They have reported an increase in brake thermal efficiency of 63.11% over diesel for neem oil of B100 at part load while it decreases by 11.2% at full load. At part load esters of neem oil was found to be better as it reduces NOx and HC with improved brake thermal efficiency. Brake specific energy consumption of neem oil methyl ester was lower (15.06%) at part load and higher (18.27%) at full load than that of diesel.Jiafeng Sun et al [2010] focused their attention towards the higher emissions of oxides of nitrogen by the use of biodiesel in diesel engines and reviewed this aspect in their article. From their critical review they have reported that the NOx formation mechanisms are complex and affected by several different features (e.g., size, operating points, combustion chamber design, fuel system design, and air system design) of internal combustion engines. The slight differences in properties between biodiesel and petroleum diesel fuels are enough to create several changes to system and combustion behaviors of diesel engines. Further they have stated that these combined effects lead to several complex and interacting mechanisms that make it difficult to fundamentally identify how biodiesel affects NOx emissions. Also it was reported that many parameters (injection timing, adiabatic flame temperature, radiation heat transfer, and ignition delay) most strongly influence the observed differences in NOx emissions with biodiesel, leading to the inconsistency in the trends.

2. EMISSIONS OF BIODIESEL

The production and use of bio diesel creates 78% less carbon dioxide emissions than conventional diesel. Carbon dioxide is a greenhouse gas that contributes to global warming by preventing some of the sun’s radiation from escaping the Earth. Burning biodiesel fuel also effectively eliminates sulfur oxide and sulfate emissions, which are major contributors to acid rain. That’s because, unlike petroleum-based diesel fuel, biodiesel is free of sulfur impurities. Combustion of biodiesel additionally provides a 56% reduction in hydro-carbon emissions and yields significant reductions in carbon monoxide and soot particles compared to petroleum-based diesel fuel. Also, biodiesel can reduce the carcinogenic properties of diesel fuel by 94%.

2.1. JATROPHA CURCAS

It is a plant growing almost throughout India. The oil content is approximately 40%. Jatrophacurcas is a plant belonging to the family of Euphorbiaceae occurring almost throughout India. It is found in India, in a semi wild condition near villages. Jatropha plant can grow rapidly almost anywhere even on gravelly, sandy and saline soils. It has hardly any special requirement with regard to climate and soil. It can even grow in the crevices of rocks. Its water requirement is extremely low. It yields within 4 to 5 years and has a long productive period of around 50 years yielding handsome returns annually. atropha oil has a high cetane number, very close to diesel. This makes it an ideal alternative fuel compared to other vegetable oils. The flash point of Jatropha oil is around 160ºC compared to 75ºC for diesel. Due to its higher flash point, Jatropha oil has certain advantages over petroleum crude, like greater safety during storage, handling and transport. However, the higher flash point may create problems in engine starting.

2.2. COTTONSEED OIL

It is a vegetable oil extracted from the seeds of the cotton plant after the cotton lint has been removed. Cottonseed oil is rich in palmiticacid, oleic acid, linoleic acid and 10% mixture of arachidic acid, behenic acid and lignoceric acid. It contains over 50% Omega-6 fatty acids. Cotton is a soft, fluffy staple fiber that grows in a boll around the seedsof the cotton plant. The plant is a shrub native to tropical and subtropical regions around the world, including the Americas, Africa, India and Pakistan. Cottonseed oil is extracted from cottonseed, which carries around 18% oil content. Cottonseed oil is estimated to contribute nearly a fifth of the global vegetable oil production. Cottonseed is a byproduct derived through process called ginning. Global cottonseed output is estimated around 35 million tons in the recent past. Major producers of cotton in the world also dominate the oil sector with China, U.S., India, Pakistan and Brazil leading the pack. Out of this nearly 27 million are used for oil.

3. PREPARATION&EXTRACTION PROCEDUREOF BIODIESEL

Biodiesel is a renewable and substitute fuel for diesel engines derived from vegetables oils. Chemically, it is a fuel mixture of monoalkyl esters of long chain fatty acids. Biodiesel can be produced by a reaction of vegetable oil or animal fat with an alcohol such as methanol or ethanol in the presence of a catalyst (acidic or basic) to yield mono-alkyl esters. Vegetable oil was converted into its methyl ester by trans-esterification process. This involves making the triglycerides of the vegetable oil to react with methanol inthe presence of a potassium hydroxide (KOH) catalyst to produce glycerol and fatty acid ester. The known amount of (1000 ml) vegetable oil, 200 ml of methanol and 10g of potassium hydroxide are taken in a round bottom flask. The contents are stirred till ester formation began. The mixture is heated up to 65 - 70°**C** and held at that temperature without stirring for anhour, and then it is allowed to cool for 24 hours without stirring. Two layers are formed, the bottom layer consists of glycerol and the top layer is the ester. The separated ester which is alkaline in nature is water washed 4 to 5 times to make the biodiesel neutral. Then the neutralized biodiesel is heated at 103 – 105°C and water present in it is removed. After heating the biodiesel is clear. The transesterified oil is blended with diesel in the required proportions to reduce its viscosity close to that of diesel. The blends prepared are stable. It is observed that blending of transesterified vegetable oil with the conventional diesel fuel reduced the viscosity close to diesel. However the density is higher and the calorific values are lesser when compared to diesel.The sequence of trans-esterification process is shown in figures **3.1 to 3.4.**

Fig:3.1

Fig:3:2

Fig:3.3

Fig: 3.4

Fig:3.1 Vegetable oil,**Fig: 3.2** Biodiesel after first wash,**Fig.3.3** Biodiesel after second wash, **Fig: 3.4** Pure Biodiesel .

4. EXPERIMENTAL SETUP

The test engine is a 3.7 KW four stroke vertical single cylinder four stroke constant speed vertical water cooled direct injection type diesel engine with the specifications of 5BHP,1500 RPM SPEED,80mm BORE,75mm STROKE,20mm Orifice Diameter,16.6:1 CompressionRatio.The Mechanical brake drum is fixed to the engine flywheel and is mounted on a MS channel frame and was mounted on anti-vibromounts. The panel board is provided with 3 way cock, digital temperature indicator with selector switch, digital RPM indicator and U-tube manometer.

LOAD AND SPEED MEASUREMENT

The engine was coupled to a rope brake dynamometer. The engine was set to run at a constant speed of 1500 rpm. The load on the engine was varied with the help of the weights placed over hanger arranged with the dynamometer. The load applied on the engine is measured with the difference of weight placed and the spring reading. The engine being a constant speed type, irrespective of the load the speed was maintained constant and was verified by measuring the speed by a digital tachometer at various loads.

PROCEDURE

The engine was started and run at no load at a rated speed of 1500 rpm. It was run at this speed for few minutes to attain steady state and then loaded gradually from no load to full load using the brake drum dynamometer. Experiments were conducted with each of the esterified oil and diesel blends having 10%, 20%, 30%, 40% and 50% (B10-B50) esterified oil on volume basis at different load levels. Tests of engine performance on pure diesel were also conducted as a basis for comparison. The engine was allowed to run at a constant speed of 1500 rpm for about 20 minutes to attain steady state at no load conditions. Then the following observations were made from no load to full load.1.Speed of the engine in RPM (N), 2.Weight added to the hanger in kg-f (W), 3.Spring balance reading in kg-f (S), 4.Time taken for 10 CC fuel consumption in seconds (t), 5.Measurement of Smoke opacity, NOx, CO_2, CO, and HC using gas analyzer**.**

The experiment is repeated for different loads.

FORMULAE

1. Mass of fuel consumption (m_f) = (c.c / t) x (s / 1000)x 3600 kg / hr.
   Where, s = specific gravity of fuel
2. Brake power (bp) = 2πNT / (60 x 1000) Kw.
   Where T = torque.

T = (W-S+1) x ((D+d) / 2) x 9.81 N-m
Where D = diameter of brake drum = 0.37 m,d = diameter of rope = 0.016 m
3. Friction power (fp) = from graph bpvs m_f.
4. Indicated power (ip) = bp + fp
5. Specific fuel consumption (sfc) = m_f / bp kg / kw-hr.
6. Percentage of Mechanical efficiency (η_{mech}) = (bp / ip) x 100
7. Percentage of Brake thermal efficiency ($\eta_{b.th}$) = (bp / (m_f x C.V)) x 3600 x 100
Where C.V = calorific value of the fuel.

5. OPTIMIZATION OF BIODIESEL – DIESEL BLEND RATIO

The optimal blend ratio for each of the two esters viz. MEOJ and MEOC were determined on the basis of specific fuel consumption, brake thermal efficiency, smoke density, and oxides of nitrogen. For optimization, experiments were conducted using diesel and the various ester blends. The blend ratios were in steps of 10 percent upto a maximum of 50 percent.Common trends observed in the results with the selected esters are discussed as follows.

i) Specific fuel consumption

The specific fuel consumption of all the blends tested followed a similar trend as that of diesel. As the proportion of the blend increases the specific fuel consumption also increases. But with increase in brake power it decreases. The effect of blends to increase the SFC is evident at higher part loads from half the rated.

ii) Brake thermal efficiency

Brake thermal efficiency plots are found to be non-linear. Blending of biodiesel lowers the brake thermal efficiency values moderately when compared to diesel. It was observed that the brake thermal efficiency increases with increasing load until maximum brake power is reached.

iii) Smoke opacity

Smoke density of all the blends is just about linear. At higher loads the smoke opacity values are higher but at partial loads it is comparatively lower. However diesel has shown lower smoke at all conditions compared to the blends.

6. METHYL ESTER OF COTTONSEED OIL – DIESEL BLEND

i) Brake specific fuel consumption

The variation of brake specific fuel consumption of diesel and various blends of cottonseed and diesel oil at different loads is shown in **figure 6.1**. It is found that the specific fuel consumptionfor the blends B10 and B20 are 0.283 kg/kW-h and 0.274 kg/kW-h respectively at full load. These values are closer to the specific fuel consumption of diesel (0.260kg/kW-h) at full load conditions. However if the concentration of cottonseed oil in the blend is more than 20% the specific fuel consumption was found to be appreciably higher than diesel at all loads. The corresponding values for the blends B30, B40 and B50 are 0.295, 0.319 and 0.348 kg/kW-h respectively at full load conditions. Higher proportions of cottonseed oil in the blends increase the viscosity which in turn increased the specific fuel consumption due to poor spray characteristics of the fuel.

ii) Brake thermal efficiency

The variation of brake thermal efficiency of the engine with various blends of cottonseed oil with diesel is shown in **figure 6.2**. It was observed that brake thermal efficiencies of all the blends were found to be lower than diesel at all load levels. Among the blends B20 is found to have the maximum brake thermal efficiency of 30.77% at a brake power of 3.9 kW while for diesel it was 30.9% and for B50 it decreased to 25.42%. Also the brake thermal efficiency of B10 follows closely with B20 with a maximum efficiency of 29.42% at full load. For blends upto B20 the efficiency is closer to diesel since better spray characteristics in the combustion chamber resulted in complete combustion of the fuel. The effect of viscosity is not dominating till the concentration in the blend is 20%. The decrease in brake thermal efficiency with increase in cottonseed oil concentration is due to their higher viscosity and poor spray characteristics. The lower brake thermal efficiency is also due to lower calorific value of the blends.

iii) Smoke opacity

Figure 6.3 shows the variation of smoke opacity with brake power for different blends of cottonseed oil and diesel. The opacity varies from 1.6% to 26.2% from no load to full load for diesel fuel. It varies from 2.6% at no load to 39.5% at full load for the blends B10 and B50 respectively. It was observed that the smoke opacity of the exhaust gas increases with increase in load for all the blends. The opacity for diesel showed a similar trend as that of the blends, however the values were comparatively lower at all loads. It also shows that the smoke opacity increases with the concentration of cottonseed oil in the blends. This is caused mainly due to the poor atomization and combustion because of the higher viscosity of the blends particularly at higher loads and higher concentration of cottonseed oil in the blends.

iv) CO_2 emission

Figure 6.4 shows the emission levels of CO_2 for various blends and diesel. Test measurements reveals that the CO_2 emission for all blends were less as compared to diesel at all loads. For diesel it varies from 2.6% to 9.1% from no load to full load. The rising trend of CO_2 emission with load is due to the higher fuel entry as the load increases. For B10 it is 2.0% at no load and 7.8% at full load. For the blends it decreases to 7.7% from 9.1% for diesel at full load. Biofuels contain lower carbon content as compared to diesel and hence the CO_2 emission is comparatively lower.

v) NO_X emission

The variation of NO_X emission for different blends is shown **in figure 6.5.**The formation of oxides of nitrogen is significantly influenced by the combustion temperature, residence time of the fuel and availability of oxygen during combustion. Normally the air fuel ratio for CI engine is 20:1 to 60:1. Air fuel ratio and the fuel injection advance are the two important parameters which significantly affect the NO_X emissions. For the blends an increase in the NO_X emission was found at all loads when compared to diesel. NO_X is formed generally at high temperatures. The exhaust gas temperature for B50 at 3.9 kW was found to be 320ºC while for diesel it was 260ºC at 3.9 kW. The exhaust gas temperatures are higher for the blends and hence the NO_X emissions are also higher. Also longer ignition delay helps in better pre mixed combustion which results in higher NO_X formation.

METHYL ESTER OF JATROPHA OIL – DIESEL BLEND

i) Brake specific fuel consumption

Figure 6.6 shows the variation of the brake specific fuel consumption of diesel and various blends of Jatropha and diesel oil at different loads. The specific fuel consumption varies from 0.283 kg/kW-h to 0.336 kg/kW-h for the blend B10 to B50 respectively at full load, while for diesel it was 0.26 kg/kW-h. The specific fuel consumption of B20 is 0.284 kg/kW-h which is also closer to diesel. However if the concentration of Jatropha oil in the blend is more than 30% the specific fuel consumption was found to be higher than diesel at all loads. At full load the values are 0.307, 0.321 and 0.336 kg/kW-h respectively for the blends B30, B40 and B50. This is because of the combined effects of lower heating value and the higher fuel flow rate due to high density of the blends. Higher proportions of jatropha oil in the blends increases the viscosity which in turn increased the specific fuel consumption due to poor atomization of the fuel.

ii) Brake thermal efficiency

The variation of brake thermal efficiency of the engine with various blends is shown in **figure 6.7** and compared with the brake thermal efficiency obtained with diesel. It was observed that brake thermal efficiencies of all the blends were found to be lower at all load levels. Among the blends B20 is found to have the maximum thermal efficiency of 29.40% at a brake power of 3.9 kW while for diesel it was 30.9% and for B50 it decreased to 26.1%. It was observed that as the proportion of jatropha oil in the blends increases the thermal efficiency decreases. The decrease in brake thermal efficiency with increase in jatropha oil concentration is due to the lower calorific value of the blends and poor atomization of the blends due to their higher viscosity.

iii) Smoke opacity

The variation of smoke opacity with brake power is shown in **figure 6.8**. For diesel the opacity is 26.2% at full load, while for the blends it varies from 27.9% to 35.7% at full load. It was observed that the smoke opacity of the exhaust gas increases with increase in load for all the blends. It also shows that the smoke opacity increases with the concentration of jatropha oil in the blends. At part loads the rate of rise in smoke opacity is less while at higher loads there is a steep increase in the opacity. This is caused mainly due to the poor volatility and improper mixing of the fuel droplets with air because of the higher viscosity of the blends.

iv) CO_2 emission

Figure 6.9 shows the emission levels of CO_2 for various blends and diesel. For diesel it was 9.1%. For a blend of B10 it decreased to 8.9% and for B50 it was the lowest at 7.1%. Measurements have shown that the CO_2 emission for the blends were less as compared to diesel ranging from 2% to 8.9% from no load to full load. Higher density of the blends increases the fuel flow rate as the load increases which in turn increases the CO_2 emission with load. As stated in section 6.1.1 Biodiesel contains lower carbon content as compared to diesel and hence the CO_2 emission is comparatively lower.

v) NO_X emission

The variation of NO_X emission for different blends is indicated in **Figure 6.10**. NO_X is formed generally at high temperatures. The exhaust gas temperature for the blends are higher (290ºC) than diesel (260º) due to the slow combustion of biodiesel. The NO_X emission for diesel and all the blends followed an increasing trend with respect to load. NO_X emission varies from 1545ppm for diesel to 1696 ppm for B50 at full load. For the blends an increase in the emission was found at all loads when compared to diesel. Since the exhaust gas temperatures are higher the NO_X emissions are also higher. Also the longer ignition delay results in better heat release during combustion which reflects in higher exhaust gas temperatures.

7. OPTIMUM BLENDS

In this experimental investigation to optimize the blend proportion of MEOC and MEOJ the following results were obtained based on the performance and emission characteristics. The following table presents the details of optimum blendsMEOC B20 and MEOJ B10. The optimal blend for MEOC with diesel is 20% by volume and The optimal blend for MEOJ with diesel is 10% by volume

Summary of optimal blends based on performance and emission

Criteria Fuels	SFC	$\eta_{b.\ th}$	Smoke	NOx	Overall
MEOC	B20	B20	B10	B10	B20
MEOJ	B10	B20	B10	B10	B10

8. PERFORMANCE CHARACTERISTICS

As far as the performance is concerned diesel is better and Methyl ester blends are closer to diesel. The results of experimental investigation carried out to compare optimal blends (B20 of MEOC and B10 of MEOJ) with diesel are discussed in the following section

The lowest fuel consumption of 0.274 kg/kW-h is found for B20 of MEOC. The highest fuel consumption of 0.286 kg/kW-h at full load is observed for B10 of Jatropha. The combined effect of viscosity and density causes a change in the specific fuel consumption. The specific gravity of methyl ester of Cottonseed oil (0.878) is comparatively lower than Jatropha (0.890) which might have resulted in lower fuel consumption for MEOC.

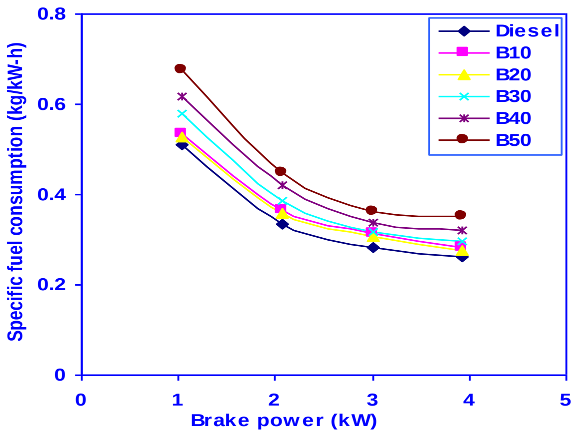
The combustion characteristics of ester blends are closer to diesel at part loads. But at higher loads the lower calorific value and the higher viscosity of the blends resulted in a decrease in the brake thermal efficiency. At full load B20 MEOC has a maximum brake thermal efficiency of 30.7 %. This is very much the same as that for diesel which has a thermal efficiency of 30.9 % at full load. The presence of oxygen in biodiesel aids combustion which causes only a minor variation in the brake thermal efficiency.

9. EMISSION ANALYSIS

The emission of carbon monoxide of all the blends of all the esters is very much lesser (0.01%) with diesel (0.03%) being the bench mark. Hence variation of CO is insignificant. The HC emission of all the blends followed a similar trend as that of diesel, but comparatively the emissions are lower. The HC emission for diesel was found to be 40% at full load where as it is 13% for MEOC B20 and 27% for MEOJ B10. The presence of oxygen in the biodiesel aids combustion and hence the hydrocarbon emission reduced.

It is observed that at full load B20 of MEOJ results in low smoke opacity in the order of 27.97 %. The rate of rise in smoke opacity is quiet high at loads higher than half the rated. This is due to the higher entry of fuel due to higher density of the blends.

NOx emission depends on adiabatic flame temperature, spray characteristics, oxygen content and availability of nitrogen during the reaction. The spray characteristics depend on droplet size, droplet momentum and degree of mixing with air and radiation heat transfer. Any change in any of these properties will cause a change in NOx emission. The trend shows that NOx formation increases as brake power increases.



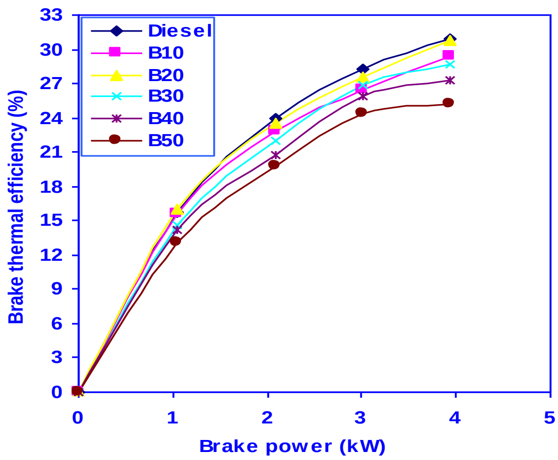
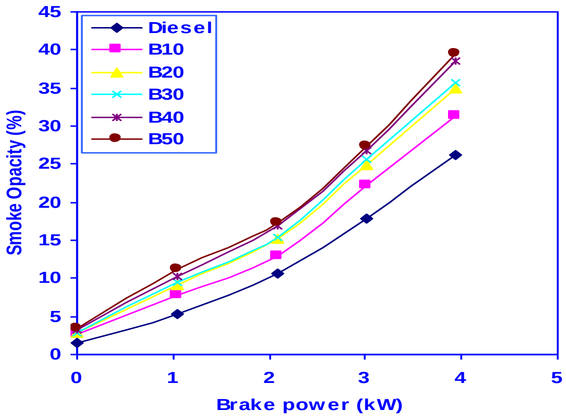


Figure 6.1 Specific fuel consumption with different blends of MEOCoil ,**Figure 6.2** Brake thermal efficiency with different blends of MEOC oil



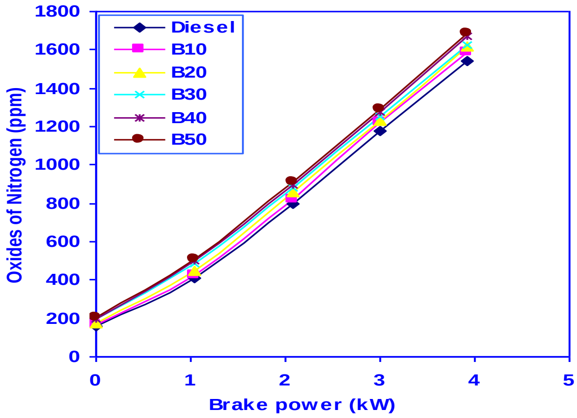
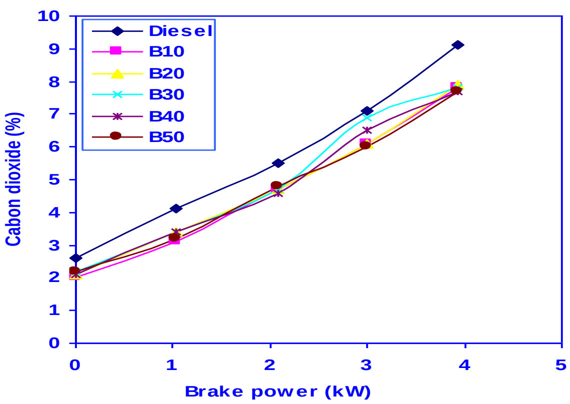


Figure 6.3 Smoke opacity with different blends of MEOC oil ,**Figure 6.4** Carbon dioxide emissions with different blends of MEOC oil



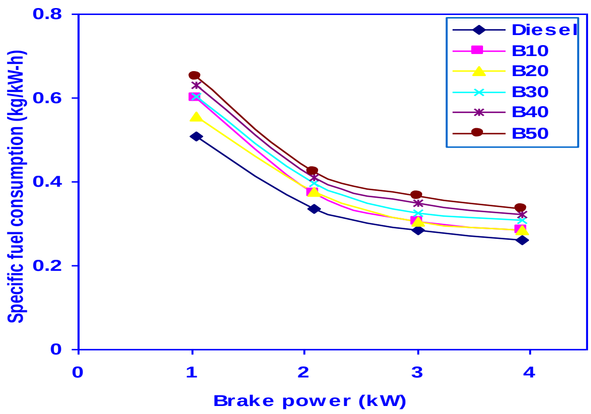
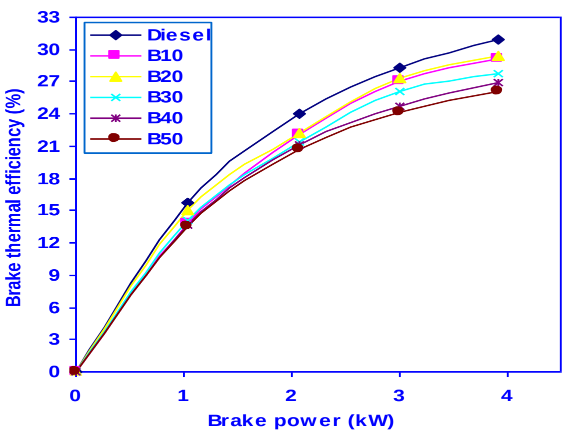


Figure 6.5NOx emissions with different blends of MEOCoil ,**Figure 6.6** Specific fuel consumption withdifferent blends of MEOJ oil



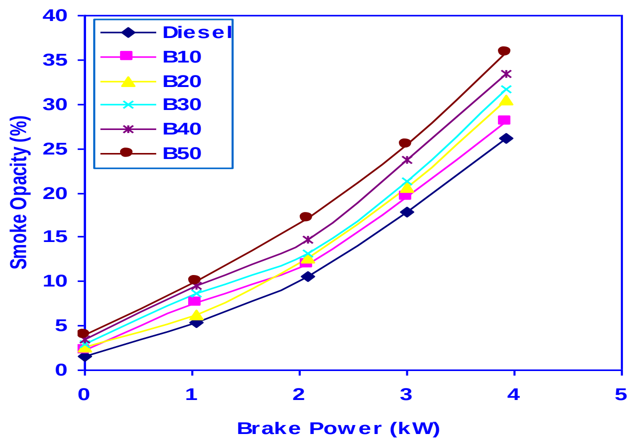


Figure 6.7 Brake thermal efficiency with different blends of MEOJ oil ,**Figure 6.8** Smoke opacity with different blends of MEOJ oil

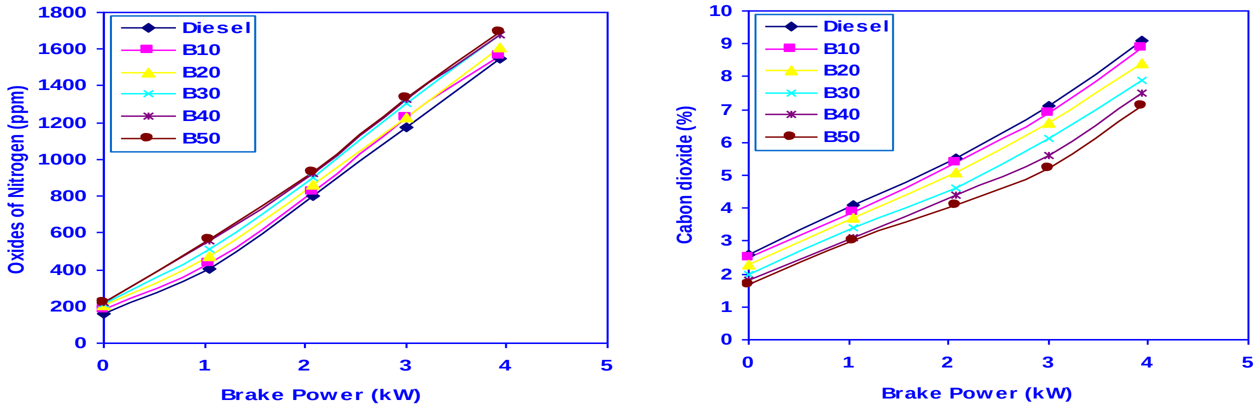


Figure 6.10 Carbon dioxide emissions withdifferent blends of MEOJ oil,**Figure 6.9**NOx emissions with different blends of MEOJ oil

10. RESULTS AND DISCUSSION

Compression Ignition engine is a naturally aspirated engine. The air is compressed and fuel is injected just before the desired start of combustion. The quantity and quality of fuel injection plays a vital role in the power output of the engine. The performance and emission parameters are based on the correlation of the combustion parameters like cylinder pressure, rate of pressure rise, ignition delay, combustion duration etc. Hence a series of engine tests were carried out using diesel and biodiesel to find out the effect of various blends on the performance and emission characteristics of the engine. Investigations are carried out on the engine mainly to study the effect of specific fuel consumption, brake thermal efficiency, and exhaust gas temperature and emissions such as NO_X, CO, CO_2, and HC.

The optimal blend for each of the oils tested were found by ranking the critical parameters viz specific fuel consumption, brake thermal efficiency, smoke opacity and NO_X emissions. It was found that exhaust gas temperature and NO_X emission increases with increase in bp for all the cases. A detailed discussion on the blends and the emissions such as NO_X, CO_2, and smoke opacity were also presented here under to understand the behavior of the engine running on biodiesel.

11. CONCLUSIONS

The following are the major conclusions from the study of results obtained from diesel engine using biodiesel.

- Among the various blends tested, the blends containing up to 30% Jatropha oil have viscosity values close to that of diesel fuel. The blend containing 40% vegetable oil has a viscosity slightly higher than that of diesel. Heating the blends reduced the viscosity further. The viscosity of the blends containing 70% and 60% vegetable oil became close to that of diesel in the temperature ranges of 70–75ºC and 60–65°C, respectively. From the engine test results, it is established that up to 50% Jatrophacurcas oil can be substituted for diesel for use in a C.I. engine without any major operational difficulties. 70–80% of diesel may be added to Jatropha oil to bring the viscosity close to diesel fuel and thus blends containing 20–30% of Jatropha oil can be used as engine fuel without preheating. From the properties of the blends it was observed that biodiesel containing more than 30% Jatropha oil has high viscosity compared to diesel. The higher density of blends containing a higher percentage of Jatrophacurcas oil has led to more discharge of fuel for the same displacement of the plunger in the fuel injection pump, thereby increasing the specific fuel consumption (SFC). A reasonably good thermal efficiency of 22.44% was also observed with the 50:50 Jatropha/Diesel

blend. Maximum thermal efficiency of 27.11% was achieved with diesel, whereas a thermal efficiency of 18.52% was observed using Jatrophacurcas oil.
- Based on the performance and emission characteristics B20 of Cottonseed oil and B10 of Jatropha oil were found to be the optimum blends among all the blends tested.

- Brake thermal efficiency values at maximum brake power for these optimum blends are 30.7% and 29.1% compared to 30.87% for base diesel.
- Smoke emissions are lower (27.97%) for B10 of Jatropha oil among the blends while for diesel it was 26.2%.
- Among the blends B20 of Cottonseed oil was found to have the highest brake thermal efficiency of 30.74% and lowest specific fuel consumption of 0.274 kg/kW-h at a brake power of 3.92 kW.
- The brake thermal efficiency of diesel is always found to be higher. It was found to be 30.87% at a brake power of 3.92 kW.
- CO_2 emissions of all the blends were lower compared to diesel.
- Optimum blend of Jatropha oil with diesel was 10% by volume.
- Optimum blend of Cottonseed oil with diesel was 20% by volume.

➢ Considering the SFC, brake thermal efficiency, NO_X and Smoke opacity B20 of MEOC is found tobe the overall optimum.

12. FUTURE SCOPE

The following are suggested as future work for the investigations on the use of biodiesel in a DI diesel engine.

- Study on retarding the fuel injection timing for the optimum blends to reduce the emissions without compromising much in thermal efficiency.
- Study on the effect of additives on the combustion, performance and emission characteristics of the biodiesel.
- Study on the effect of compression ratio on the combustion and exhaust gas analysis of the biodiesel.

APENDICES

APPENDIX –A : PROPERTIES OF DIESEL

Fuel Property	Diesel
Fuel Standard	ASTM D975
Lower Heating Value, Btu/gal	~129,050
Kinematic Viscosity, @ 40 ^{o}C	1.3-4.1
Specific Gravity kg/l @ 60 ^{o}F	0.85
Density, lb/gal @ 15 ^{o}C	7.079
Water and Sediment, vol%	0.05 max
Carbon, wt %	87

Hydrogen, wt %	13
Oxygen, by dif. Wt %	0
Sulfur, wt %	0.05 max
Boiling Point, ^{o}C	180 to 340
Flash Point, ^{o}C	60 to 80
Cloud Point, ^{o}C	-15 to 5
Pour Point, ^{o}C	-35 to -15
Cetane Number	40-55

APPENDEX: B :SPECIFICATIONS OF EXHAUST GAS ANALYSER

AUTOMOTIVE EXHAUST GAS ANALYSER		Model : DiGas 444 Make: AVL	
Parameter	Range	Resolution	Accuracy
NO_X (ppm)	0 – 5000 ppm vol.	1 ppm vol.	± 50 ppm vol
CO_2 (%)	0– 20 % vol	0.1 % vol	± 0.5 % vol
CO (%)	0 – 10 % vol	0.01 % vol	± 0.03 % vol
HC (ppm)	0 – 20000 ppm vol	1 ppm vol	± 5 % of value
O_2 (%)	0 – 22 % vol	0.1 % vol	± 0.5 % vol

APPENDIX –C:PROPERTIES OF SELECTED BIODIESELS USED IN THE STUDY

Test Property	MEOJ	MEOC
Density at 31ºC kg/m^3	891	873
Kinematic Viscosity at 40ºC (mm^2/s)	4.8	5.3

Flash Point (PMCC) °C, (minimum)	176	160
Calorific value kJ/kg	40347	39958
Pour point °C	4	3
Sulphur, mg/kg, (max)	12	13
Carbon Residue (Ramsbottom), % by mass,	0.09	0.09
Moisture by D&S method %	0.14	0.21

APPENDIX –D:DENSITY OF DIESEL, SELECTED BIODIESELS AND THEIR BLENDS

Fuel	Biodiesel blends – Density(gm/cm^3) at 30^0C				
	B10	B20	B30	B40	B50
Diesel	0.824				
MEOJ	0.837	0.851	0.864	0.878	0.891
MEOC	0.834	0.844	0.853	0.863	0.873

APPENDIX –E:CALORIFIC VALUE OF DIESEL, SELECTED BIODIESELS AND THEIR BLENDS

Fuel	Biodiesel blends – calorific Value(kJ/kg)				
	B10	B20	B30	B40	B50
Diesel	42800				
MEOJ	42309	41818	41328	40837	40347
MEOC	42231	41663	41094	40526	39958

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