Performance Analysis of CI Engine using Pongamia Pinnata (Karanja) Biodiesel as an Alternative Fuel

P. L. Naik[1], D. C. Katpatal[2]

[1,2]Department of Mechanical Engineering, Kavikulguru Institute of Technology & Science, Ramtek, India

Abstract: ***Biodiesel is an alternative fuel of diesel, is described as fatty acid methyl ester from vegetable oils or animal fats. The main objectives of the present work is to reduce higher viscosity of Pongamia pinnata (Karanja) oil using esterification followed by transesterification and to assess the performance and emission characteristics of diesel engine. The important properties of engine fuel such as density, viscosity, flash point and calorific value of Karanja methyl ester were compared with diesel fuel. Various proportions of Karanja oil methyl ester blends (10%, 20%, and 30%) were used for conducting the performance test at varying load conditions. Engine parameters such as brake specific fuel consumption, brake thermal efficiency were calculated and emission parameter such as emission of carbon dioxide, hydrocarbons and oxide of nitrogen gases in exhaust were recorded. By using Karanja oil methyl ester blends with diesel fuel, the result showed that the brake thermal efficiency of biodiesel blends with diesel fuel wee less as compared to diesel fuel. Fuel consumption was increased with increase in blend proportions. It is found that the emission level of CO and HC level decreased with increased in blend proportion in diesel fuel. NOx emission increased with increase in blend proportion in diesel fuel. The test results indicate that biodiesel B-20 and lesser can be used as an alternative without any modifications of diesel engine.***

Keywords: Karanja oil methyl ester, Karanja, performance, exhaust emissions.

1. Introduction

Biodiesel is a renewable fuel produced from vegetable and animal fats that can be used in diesel engine with little or no modification. Biodiesel is typically blended with diesel fuel in formulations referred to as B-2 (2% biodiesel and 98% diesel), B-5 (5% biodiesel and 95% diesel), B-20 (20% biodiesel and 80% diesel). Blends of 20% biodiesel and lower can be used in diesel equipment without any modification in diesel engine. Biodiesel can also be used in its pure form (B-100), but it may require engine modifications to avoid maintenance and performance problems. Biodiesel is gaining more and more importance as an alternative fuel due to the depletion of petroleum resources and price hike of petroleum products. Many researchers carried out performance and emission tests of biodiesel fuels on diesel engine. It is renewable, safe and non polluting source of energy. Chemically biodiesel is referred as monoalkyl esters of long chain fatty acid derived from renewable biological sources. The high viscosity of vegetable oil and low calorific value affects the atomization and spray formation of fuel, leading to incomplete combustion, carbon deposition, injector choking and piston ring sliding. Transesterification is commonly used to reduce the viscosity of non edible vegetable oil to produce clean and environmental friendly fuel. There are various vegetable oil available for production of biodiesel such as sunflower oil, rubber oil, jatropha oil, karanja oil, soyabean oil, rapeseed oil, mahua oil, palm oil, rubber seed oil etc. Sunflower oil, soyabean oil, palm oil are edible oils hence it cannot be used for biodiesel production. On the other hand Karanja oil, Jatorpha oil etc are non edible oil and are attractive due to easy availability and low production cost. Dharmadhikari HM et al[10] carried number of experiments using Karanja methyl ester blends and Neem methyl ester blends with diesel at different injection pressure. Experiments were performed on Kirloskar AV1 stationary single cylinder four stroke diesel engine of maximum power 3.7KW and at constant speed 1500 rpm. Authors reported that brake thermal efficiency of the engine decreased around 6% for all blend in comparison with diesel and brake specific fuel consumption was slightly more for B-10 and B-20. CO and HC emissions were observed to be less for B-10 and B-20, NO_x emission decreased by 39% for B-10 and 28% for B-20 compared with diesel. Rehman et al[11] used blends of biodiesel obtained from a mixture of Mahua oil and Simarouba oil with High Speed Diesel. Experiments were conducted on 10.3KW single cylinder water cooled direct injection diesel engine. Based on the performance and emission authors reported that the blend B-10 was selected for long term use. Singaram Lakshamana[12] provided a summary of study of development of biodiesel as an alternate fuel for IC engine. Author reviews technique used to produce biodiesel and provides a comprehensive analysis of the benefits of using biodiesel over other fuels. He reported that the biodiesel B-20 and less can be used as an alternative fuel without much modification of diesel engine and almost the same performance of a diesel engine with a petro diesel fuel.

2. Preparation of Biodiesel by Transesterification process

Transesterification process is the reaction of triglyceride (fat/oil) with an alcohol in the presence of acidic, alkaline or lipase as a catalyst to form monoalkyl ester that is biodiesel and glycerol. The presence of strong acid or base accelerates the reaction. The main purpose of transesterification is to reduce the high viscosity of oil which is suitable for CI engine. In this study, Karanja methyl ester (KOME) is obtained by reacting Karanja oil with methanol in the presence of base catalyst. The Karanja oil is first filtered to remove solid impurities then it is preheated at100°C for half an hour to remove moisture. A two stage process is used for transesterification of Karanja oil. The first stage is esterification to reduce free fatty acid content in Karanja oil with methanol (99% pure) and acid catalyst (98% pure) heated for one hour at 60-65°C on magnetic stirrer. After esterification, the esterified oil washed using water. The washing is carried out in a separating funnel. The hot water having temperature as that of esterified oil added in a separating funnel. Impurities like dust, carbon content; sulfur content is washed away with water. After washing, the esterified oil was fed to the transesterification process. The solid catalyst (1% by wt) was dissolved in methanol and added into esterified Karanja oil while heating. This mixture is heated for 60 minutes. Once the reaction is complete, it is allowed for settling for 10-12 hours in a separating funnel. The products formed during transesterification were Karanja oil methyl ester and glycerin. The bottom layer consists of glycerin, excess alcohol, catalyst impurities and traces of un reacted oil. The upper layer consists of clean amber colored Karanja oil methyl ester. After settling, the glycerol layer is removed. The separated biodiesel is taken for characterization. The chemical reaction involved in the process is mentioned below. The flowchart for biodiesel production is shown in Fig. 2.

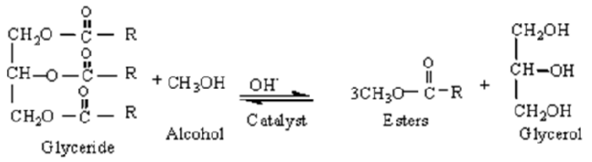


Figure 1: Chemical reaction for transesterification process[7]

pH had been checked regularly during esterification and transesterification reaction. A successful transesterification reaction is signified by the separation of the ester and glycerol layers after the reaction time. Transesterification is one of the reversible reactions. However the presence of catalyst accelerates the reaction. This process is similar to hydrolysis except then alcohol is used instead of water. This process has been widely used to reduce high viscosity of triglycerides [4].

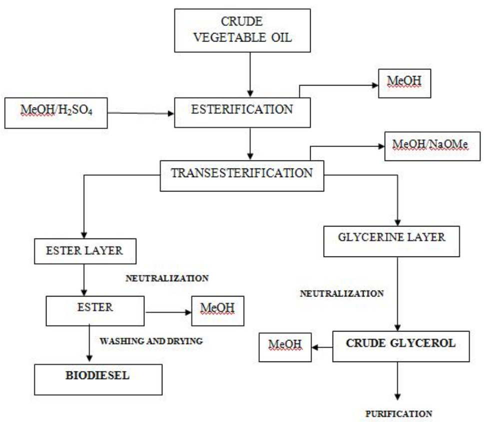


Figure 2: Flow chart of biodiesel production from Karanja oil

3. Properties of biodiesel and its blends

3.1 Properties of Karanja oil and its biodiesel

Properties of Karanja crude oil and pure biodiesel obtained from transesterification process were measured at Chemistry Department and Research & Development, Mechanical Engineering Department of KITS, Ramtek shown in Table 1.

Table 1: Properties of Karanja oil and its biodiesel

Sr. no.	*Property*	*Unit*	*Karanja oil*	*B100*
1	Density in gm/cc	gm/cc	0.926	0.905
2	Viscosity (at 40°C)	cst	41.8	8.9
3	Flash point	°C	225	150
4	Calorific value	KJ/Kg	30075	36120.3

3.2 Preparation of biodiesel blends

The biodiesel obtained from Karanja oil by transesterification were blended with Diesel in three different portions, i.e., 10%, 20%, 30% by volume. For obtaining Karanja biodiesel blend B-10, 90% of diesel is mixed with 10% of Karanja oil by volume. B-20 contains 20% biodiesel and 80% diesel by volume and B-30 contains 30% biodiesel and 70% diesel by volume.

3.3 Properties of diesel and biodiesel blends

Properties of diesel and biodiesel blends with diesel were measured at Chemistry Department and Reseach & Development Department of KITS, Ramtek were listed in Table 2.

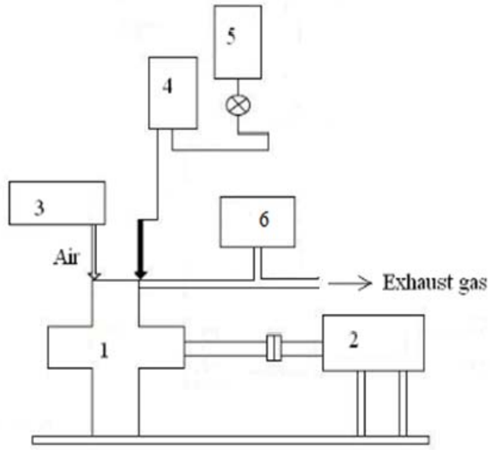
Table.2: Properties of diesel and biodiesel blends

Sr. No.	*Property*	*Unit*	*Diesel*	*B-10*	*B-20*	*B-30*
1	Density	Kg/m^3	840	843	850	867
2	Viscosity (40°C)	cst	4	4.3	5.2	5.5
3	Flash point	°C	65	65	67	70
4	Calorific value	KJ/Kg	42390	40420.2	39150.2	38840.2

4. Testing and observations

4.1 Experimental setup

Fig. 3 shows schematic diagram of the experimental setup. The engine set up shown is single cylinder water cooled diesel engine. The engine has rated output 5.2kw at speed 1500rpm with compression ratio 17.5, injection pressure $180 kg/cm^3$ and coupled with rope break dynamometer. The detailed specification of engine is given in Table no.3. Performance test are carried out on compression ignition engine using various blends of biodiesel and diesel as fuel.



1. Engine 2. Dynamometer 3.Air plenum 4.U-tube manometer 5. Dual biodiesel tank 6.Exhaust gas analyzer

Figure 3: Experimental setup

4.2 Engine technical specifications

Table 3: Engine specifications

Engine speed	1500 rpm
BHP	5
Bore	80 mm
Stroke	95 mm
No. of cylinder	1
Dynamometer	Mechanical loading
Drum diameter	28 cm
Do	24 mm
C_d (Coefficient of discharge)	0.6

The engine was coupled to a dynamometer to provide load to the engine. A tachometer was used to measure the speed. A burette was used to measure fuel flow to the engine via fuel pump. A thermocouple with a temperature difference indicator measures the exhaust gas temperature. The ambient temperature is measured by thermometer. The cooling water temperature is measured by thermometer by taking outlet cooling water in the flask. Emission such as nitrous oxide (NO_x), carbon monoxide (CO) and unburned hydrocarbon (HC) were measured by an Exhaust gas analyzer. First, the tank was filled with conventional diesel and cooling water was supplied. Engine was started and run at no load condition for four to five minutes. Then the burette connected with fuel tank and was filled up to 20cc. Subsequently the time to consume 20cc was noted. Simultaneously the time taken for 1000ml discharge of cooling water was noted and its temperature was measured. The pressure head was calculated from the difference between the level in the U-shaped manometric tube. Finally the temperature of the exhaust gas was noted. The same procedure was followed with successive increase in load maintaining the speed constant. For different blends of biodiesel the engine was allowed to run continuously until the entire earlier diesel was consumed. Then the engine was allowed to run for five minutes for obtaining reliable results. The same procedure for conventional diesel was followed for different blends at different loads.

5. Engine performance and emission parameters for Karanja biodiesel blends compared with diesel

5.1 Engine load V/S BSFC

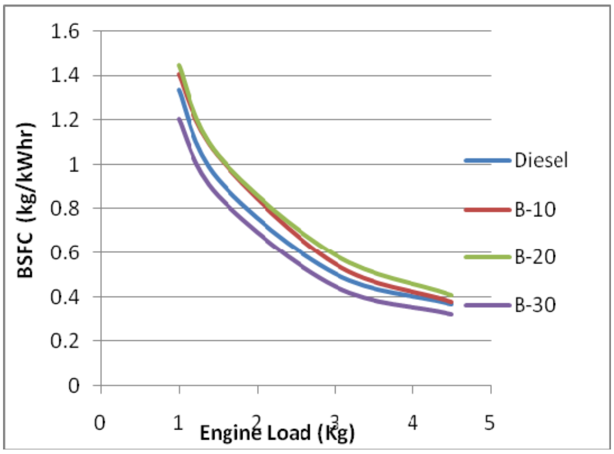


Figure 4: Variation of brake specific fuel consumption at different engine load condition

Figure 4 shows the variation of brake specific fuel consumption at different engine load condition. It can be observed from the figure that the BSFC for B-10 is nearer to that of diesel fuel. The possible reason may be that at higher load, the cylinder wall temperature is increased which reduces ignition delay leading to the improvement in combustion and reduction in fuel consumption. The availability of the oxygen in the biodiesel blend may be the reason for the lower BSFC. At lower loads, significant properties of the fuel inducted through the intake does not burn completely due to lower quantity of pilot fuel, low cylinder gas mixture and lean air fuel mixture. When two different fuels of different heating values are blended together, the fuel consumption may not reliable, since the heating value and density of the two fuels are different. In such cases the BSFC will give more reliable result.

5.2 Engine load V/S BTE

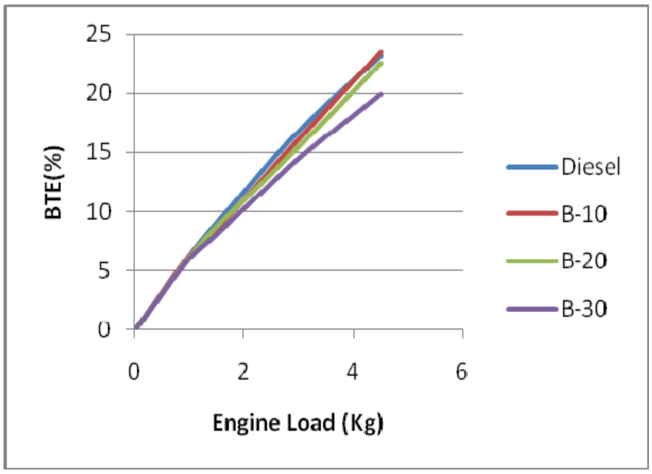


Figure 5: Variation of brake thermal efficiency at different engine load condition

Fig. 5 shows the variation of the brake thermal efficiency at different engine load condition for diesel fuel and Karanja methyl ester-diesel fuel blends. It can be observed from the figure that, B-20and B-30 shows brake thermal efficiency comparable to diesel fuel. There was a reduction in brake thermal efficiency with the increase in biodiesel proportion in the fuel blends. The possible reason for low efficiency may be due to low calorific value, higher viscosity and higher density of the biodiesel of Karanja oil.

5.3 Engine load V/S Volumetric Efficiency

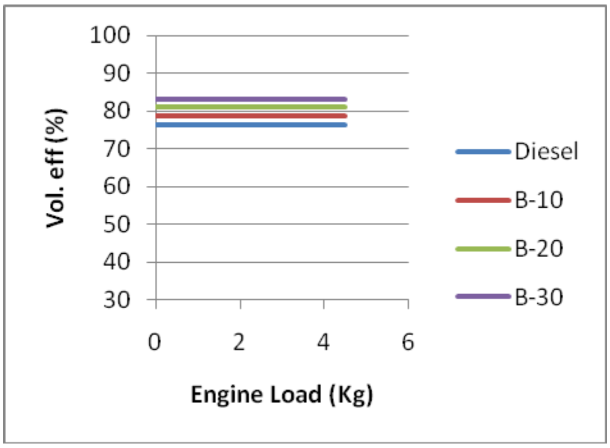


Figure 6: Variation of volumetric efficiency at different brake power

Fig. 6 shows the variation of volumetric efficiency at different brake power. It can be seen that the volumetric efficiency of Karanja methyl ester blends increases with blend concentration. Volumetric efficiency was constant for all loading conditions because injection pressure of the engine is constant. The possible reason for increased volumetric efficiency with increased blend concentration may be, because the Karanja methyl ester having higher bulk modulus compared to diesel.

5.4 Variation of exhaust gas temperature at different engine load conditions

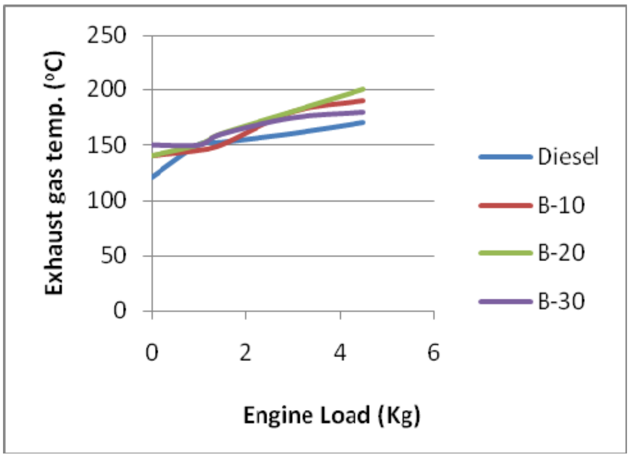


Figure 7: Variation of exhaust gas temperature at different engine load conditions

Fig. 7 shows the variation of the exhaust gas temperature at different engine load conditions for the fuel blends. Exhaust gas temperature was found to increase in both concentration of biodiesel in blends and engine load. The exhaust gas temperature rises from 120°C at no load to 200°C for various blends. The increase in EGT with engine load is due to the fact that a higher amount of fuel is required in the engine to generate extra power needed to take up conditional loading. Exhaust gas temperature for B-30 is highest. For the diesel fuel the exhaust gas temperature is lowest among all biodiesel blends.

5.5 Engine load V/S NOx

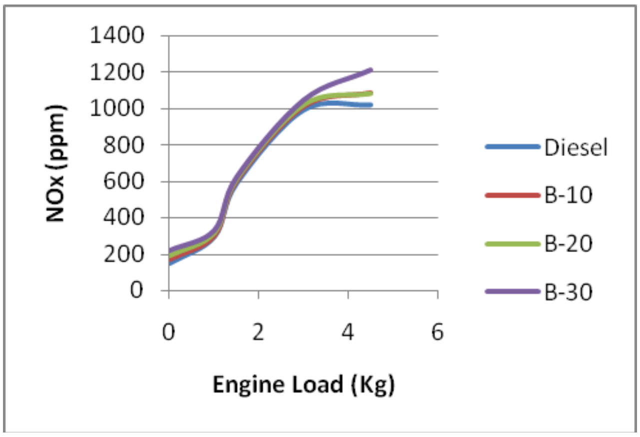


Figure 8: Variation of NOx at different engine load conditions

Fig. 8 shows that the variation of NOx emission at different engine load conditions. The exhaust gas temperature with blends having high percentage of Karanja oil is high as compared to diesel at higher loads. The slower burning character of the fuel causes a slight delay in the energy release, which results in higher temperature in later part of power stroke and exhaust stroke. Increased exhaust gas temperature is due lower heat transfer and the fact that biodiesel has some oxygen content in it which facilitate NOx formation.

5.6 Engine load V/S CO

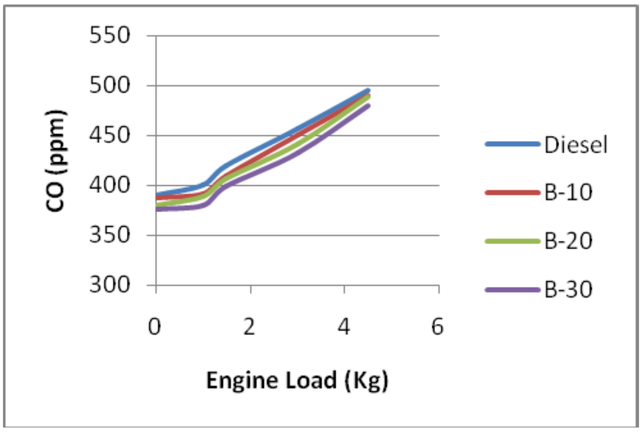


Figure 9: Variation of CO at different engine load conditions

Fig. 9 shows the variation of CO at different engine load conditions for various blends. It has been observed that CO emission was found to decrease with the increase in proportion of biodiesel in the blends. CO emissions are increased with increase in engine load. The lower CO emission of biodiesel compared to diesel is due to the presence of biodiesel which helps in complete oxidation of fuel. Further it can be seen that CO increased on further loading, the excess fuel required led to the formation of more smoke, which might prevented the oxidation of CO into CO_2, which results increased emission.

5.6 Engine load V/S HC

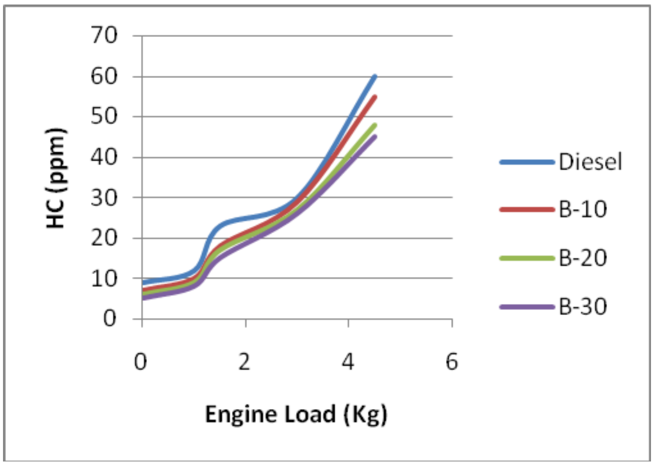


Figure 10: Variation of HC at different engine load conditions

Fig. 10 shows the variation of HC at different load conditions for various blends. Hydrocarbons in exhaust are due to incomplete combustion of carbon compounds in the blends. The values of HC emission decrease with increase in proportion of biodiesel in the fuel blends. The emissions of unburnt hydrocarbon for biodiesel exhaust are lower than that of diesel fuel. The possible reason for decrease in unburnt HC may be higher cetane number and increased gas temperature. The higher cetane number of biodiesel results decrease in HC emission due to shorter ignition delay. Increased temperature of burnt gases in biodiesel fuel helps in preventing condensation of higher hydrocarbon thus reducing unburnt HC emissions.

6. Results and discussions

Karanja methyl ester (biodiesel) and Diesel were analyzed for physical and chemical properties given in Table 1 and 2. Higher viscosity is a major problem in using vegetable oil as fuel for diesel engine. In the present study, viscosity was reduced by esterification followed by tranesterification from 41.8cst to 8.9cst. Density, viscosity, flash point of Karanja biodiesel was quite high compared to diesel. Therefore Karanja methyl ester is extremely safe to handle. Performance and emission tests were conducted using various blends of Karanja methyl ester (biodiesel) with diesel.

Brake thermal efficiency of Karanja oil methyl ester found lower than that with diesel fuel. However thermal efficiencies of Blends up to B-20 were very close to diesel. Volumetric efficiency for diesel and Karanja methyl ester blends was constant at different BP since the injection pressure of single cylinder diesel engine was constant. BSFC was found to increase with increase in blend proportion as compared to diesel fuel in the entire load range. The exhaust gas temperature is found to increase with concentration of Karanja methyl ester blend due to coarse fuel spray formation and delayed combustion. NOx, CO and HC emissions were measured for diesel and Karanja methyl ester blends. NOx was found to increase with increase in blend proportion. Nitrogen content of the fuel affects the NOx emissions by formation of fuel NOx. CO and HC emission decreases with increase in blend proportion. Karanja methyl ester found good results as compared to other biodiesel.

7. Conclusion

The combustion and emission characteristics of single cylinder four stroke diesel engine fueled with Karanja biodiesel and its blends with diesel were analyzed and compared to standard diesel fuel. The fuel properties like density, flash point, viscosity and calorific value of B-10 and B-20 are very similar to diesel fuel thus biodiesel B-20 and less can be used as an alternative fuel without modification of diesel engine and found improved performance and emission characteristics of diesel engine with diesel fuel. Biodiesel use could preserve the environmental air quality by decreasing harmful emissions released by regular diesel fuel. Biodiesel are produce locally, which decreases the nation's dependence upon foreign energy and can employ hundreds or thousands of workers, creating new jobs in rural areas and crop cultivation of biodiesel plants will boost the rural economy.

References

[1] S.N. Bobade and V.B. Khyade "Preparation of Methyl Ester (Biodiesel) from Karanja (Pongamia pinnata) Oil." Research Journal of Chemical Sciences, Vol. 2(8), 43-50, August (2012).
[2] R. K. Singh, A. Kiran Kumar and S. Sethi. "Preparation of Karanja oil Methyl Ester.", Offshore World, April-May 2006.
[3] S.N. Bobade and V.B. Khyade "Detail study on the Properties of Pongamia Pinnata (Karanja) for the Production of Biofuel.", Research Journal of Chemical Sciences, Vol. 2(7), 16-20, July (2012).
[4] P.L.Naik and D.C. Katpatal, "Optimization of effective parameters of Pongamia pinnata (Karanja) biodiesel using Taguchi method", International Journal of Engineering Research and Application, Vol.3, Issue 4, Jul-Aug 2013, pp701-706.
[5] S.Antony Raja, D.S.Robinson Smart, and C.Lindon Robert Lee. "Biodiesel production from Jatropha oil and its Characterization." Research Journal of Chemical Sciences Vol. 1 (1) April (2011).
[6] SunTae Kim, Bongbeen Yim, Youngtaek Park. "Application of Taguchi Experimental Design for the Optimization of Effective Parameters on the Rapeseed Methyl Ester Production.", Environ. Eng. Res. 2010 September, 15(3): 129-134.
[7] Tint Tint Kywe, Mya Mya Oo. "Production of Biodiesel from Jatropha Oil (Jatropha curcas) in Pilot Plant.", World Academy of Science, Engineering and Technology, Vol. 38, February 2009.
[8] F. Halek, A. Kavousi, and M. Banifatemi. "Biodiesel as an Alternative Fuel for Diesel Engines." World

Academy of Science, Engineering and Technology 57 2009.
[9] T. Ganpathy, R.P. Gakkhar, K. Murugesan, "An Analytical and Experimental study of Performance on Jatropha Biodiesel Engine", Thermal Science, Vol. 13, No.3, pp69-82, 2009.
[10] H.M. Dharmadhikari, P. Ravikumar, S. Srinivasa Rao, "Performance and Emissions of CI Engine Using Blends of Biodiesel and Diesel At Different Injection Pressures", International Journal of Applied Research in Mechanical Engineering, VOl. 2, Iss 2, 2012.
[11] H. Raheman, P.C. Jena, S.S. Jadhav, "Performance of a Diesel Engine with Blends of Biodiesel (from a mixture of oils) and High-Speed Diesel.", International Journal of Energy and Environmental Engineering 2013.
[12] Singaram Lakshamana., "Biodiesel: An Ecofriendly Alternate Fuel for the Future- a Review", Thermal Science, 2009.Vol.13.No.3, pp185-199.
[13] A. Haiter Lenin, R. Ravi, K. Thyagarajan, "Performance Characteristics of a Diesel Engine Using Mahua Biodiesel as Alternate Fuel." Iranica Journal of Energy and Environment. Vol. 4, Iss. 2,136-141,2013.
[14] Jinlin Xue, T.E. Grift, A.C. Hansen, "Effect of Biodiesel on Engine Performances and Emissions." Journal Homepage: www.elsevier.com/locate/rser., 15(2011) 1098-1116.

Author Profile

P. L. Naik is a Student of final semester of P.G. course in Engineering (Heat Power Engineering) of KITS at Ramtek, Nagpur University, India.

D.C. Katpatal is an Assistant Professor of KITS, Ramtek in Mechanical Engineering Department. He has 14 years teaching experience. He has published 07 technical papers in National and International conference and is a life member of ISTE. He is pursuing PhD from VNIT Nagpur, India.