

# **Performance and Emission Testing of Neem Oil Methyl Ester (Biodiesel) in Internal Combustion Engine**

Anand Prakash Mall

M.Tech. (Thermal) Scholar, Dept. of Mechanical Engineering, Delhi Technological University, New Delhi, India

**ABSTRACT:** Normally, the diesel engine produce excessive knocking that can damage the engine, besides that it produces gases like carbon monoxide, nitrogen oxides, unburnt hydrocarbon, smoke, soot and other forms of black carbon as well as particulate matter, such as lead. All the gases are harmful to the environment and human kind. They can cause greenhouse effect, acid rain and air pollution and thus harm the environment. Due to these effects, human beings may suffer from various diseases, such as lung cancer, breathing difficulties, poisoning and skin cancer etc.

In this research paper the effects of various parameters on performance of Kirlosker engine for different blends of diesel and biodiesel (extracted from crude neem oil feedstock by applying biodiesel production technique) have been analyzed.

**KEYWORDS:** Biodiesel [Neem Oil Methyl Ester (NOME)], Engine Emissions, Engine Performance, NOME (Biodiesel) Blends (B20, B20, B30).

## **I. INTRODUCTION**

The use of alternative fuels instead of conventional fossil fuels is becoming increasingly significant due to decreasing petroleum reserves and increasing greenhouse gases, all of which lead to global warming, ozone depletion and political and health concerns (Fukuda et al., 2001). Plant oils have been used as alternative fuels for many years, since they are renewable and readily available. However, these oils cannot be used directly as fuel sources in diesel engines due to: (a) high viscosity which leads to poor fuel atomization during the injection process, (b) low volatility and (c) polymerization which results in deposit formation, incompleteness combustion and poor emissions (Meher et al., 2006). To overcome these disadvantages, oils can be converted into fatty acid methyl esters (FAME) which are also known as biodiesel. Biodiesel is an alternative fuel that is non-toxic, completely biodegradable and renewable and can be adapted easily without any modification to diesel engines.

Neem is a tree in the family 'maliaceae' which grows various parts in Bangladesh. It's scientific name 'Azadirachta indica'. The evergreen tree is large, reaching 12 to 18 meters in height with a girth of up to 1.8 to 2.4 meters. The seeds have 40% oil which has high potential for the production of biodiesel. It has a higher molecular weight, viscosity, density, and flash point than diesel fuel. Neem oil is generally light to dark brown, bitter and has a strong odor that is said to combine the odors of peanut and garlic [M.A. Fazal et al., 2011].

Neem comprises mainly of triglycerides and large amounts of triterpenoid compounds. It contains four significant saturated fatty acids, of which two are palmitic acid and two are stearic acid. It also contains polyunsaturated fatty acids such as oleic acid and linoleic acids [Muthu et al., 2010]

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

## II. RELATED WORKS (LITERATURE SURVEY)

Agarwal et al. [2012] evaluated the performance, emission and combustion characteristics of Neem Oil Methyl Ester (Biodiesel) and found that Brake specific fuel consumption for biodiesel and its blends were higher than mineral diesel however brake thermal efficiency of all biodiesel blends was also higher than mineral diesel. BSCO and BSHC emissions for biodiesel fuelled engine operation were lower than mineral diesel however BSNO<sub>x</sub> emissions were higher for biodiesel blends. Combustion started earlier for higher biodiesel blends however start of combustion was slightly delayed for lower biodiesel blends in comparison to mineral diesel. Rate of heat release trends for all the biodiesel blends were almost identical to mineral diesel. Combustion duration for biodiesel blends was shorter than mineral diesel. This indicates that lower blends of biodiesel (upto B20) can be used in unmodified CI engines without any compromise in engine performance and emission characteristics.

Mishra et al. [2015] did optimization by using Taguchi method and ANOVA and found that temperature had the highest effect on the biodiesel yield followed by catalyst amount, methanol to oil molar ratio and reaction time. The result of their work using Taguchi Method showed that the maximum yields were obtained at lowest factor values. This will definitely have economic advantage on neem oil biodiesel production as low energy cost, low catalyst amount, low methanol/oil molar ratio, and low temperature are able to produce high biodiesel yield.

Mishra et al. [2015] developed two-step transesterification process to convert the high FFA oils to its mono-esters. Using 100 ml of oil, the optimum combination of parameters for pretreatment were found to be 0.45 v/v methanol-oil-ratio, 0.5% v/v H<sub>2</sub>SO<sub>4</sub> acid catalyst, 50°C and 45 min reaction time. After pretreatment of neem oil, transesterification reaction was carried out with 4.5:1 methanol-to-oil molar ratio, 1% KOH as alkaline catalyst, 75 min reaction time and 50°C reaction temperature to produce the fatty acid methyl ester. This two step process gave maximum average yield of 70±2%.

Aransiola et al. [2012] found that the emissions of CO and NO decreased with the biodiesel blends while that of NO<sub>x</sub> increased. The properties of the biodiesel, produced from neem oil feedstock, compared favourably with the values prescribed by American Standard Testing Method. The results obtained in their study would be relevant in the development of biodiesel production from neem oil especially in countries where neem oil feedstock is abundant.

Gorle et al. [2013] did performance and emissions testing of Jatropha biodiesel blends and found that BJ-20 had less brake specific fuel consumption and more brake thermal efficiency and BJ-20 and BJ-30 had nearer volumetric efficiency. If engine load increased brake thermal efficiency slightly increased in BJ-20 as compared to other. In exhaust parameter NO<sub>x</sub> was increased with increase in blend proportion and CO, HC, smoke decreased with blend proportion.

## III. PREPARATION OF NOME (BODIESEL) BLENDS:

Three different diesel-biodiesel blends were prepared as explained below.

1. B10 ( 10% biodiesel + 90 % diesel ): To prepare 500 ml of B10 Blend, 450 ml of pure diesel was taken in a beaker and it was mixed with 50 ml of biodiesel prepared from neem oil.
2. B20 ( 20 % biodiesel + 80 % diesel ) : To prepare 500 ml of B20 Blend , 400 ml of pure diesel was taken in a beaker and it was mixed with 100 ml of biodiesel prepared from neem oil.
3. B30 ( 30 % biodiesel + 70 % diesel ): To prepare 500 ml of B30 Blend , 350 ml of pure diesel was taken in a beaker and it was mixed with 150 ml of biodiesel prepared from neem oil.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

4. Calorific value of pure diesel = 43000KJ/Kg
5. Calorific value of biodiesel (NOME) = 38550 KJ/Kg
6. Density of pure diesel = 821 Kg/m<sup>3</sup>
7. Density of biodiesel (NOME) = 896.60 Kg/m<sup>3</sup>
8. The calorific value and densities for diesel and different blends of biodiesel were calculated as shown in the table1.

Table 1: Description of different blends of biodiesel

Type of blend	Amt. of biod.(ml)	Amt. of diesel(ml)	Res. Cal. val. (KJ/kg)	Res. Density (kg/m <sup>3</sup> )
Diesel	0	1000	43000	821
B-10	50	450	42555	827.4
B-20	100	400	42110	833.8
B-30	150	350	41665	840.2

## IV. EXPERIMENTAL SETUP

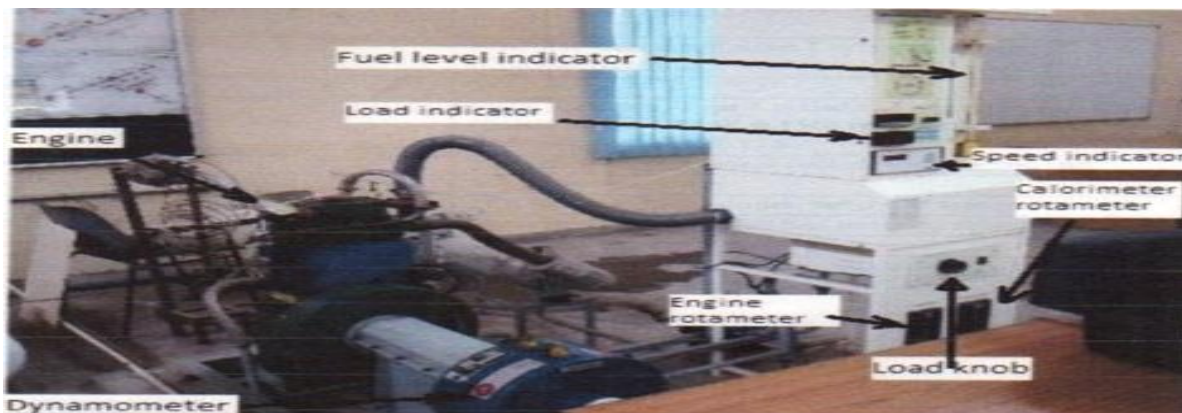


Fig.1.Experimental set-up of Kirlosker diesel engine



Fig.2. Rear view of the Kirlosker diesel engine

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

Fig.1 shows the experimental set-up of Kirlosker diesel engine and Fig.2 shows the rear view of the Kirlosker diesel engine. The setup consists of single cylinder, four strokes, Kirlosker Diesel Engine connected to an eddy current type dynamometer for loading. The setup has standalone panel box consisting of air box, two fuel tanks for duel fuel test, manometer, fuel measuring unit, transmitters for air and fuel measurements, process indicator and engine indicator. Rotameters are provided for cooling water and calorimeter water flow measurement. Engine technical specifications are given in Table 2.

Table 2: Engine Technical Specifications:

Component	Specifications
Product	Kirlosker engine test setup 1 cylinder, 4 stroke, Diesel (Computerized)
Engine Speed	1500 rpm
BHP	3.5 KW
Bore	87.5 mm
Stroke	110 mm
Swept Volume	661 cc
Software	"Enginesoft" Engine performance analysis software

## V. PERFORMANCE EVALUATIONS

All experiments were performed on a single cylinder, 4 strokes Kirlosker diesel engine. There were two separate fuel tanks in the setup, one for diesel and another for biodiesel-diesel blend. Fuel was supplied to the engine from outside tank. A 5-min warm-up period is provided before first run data collection. The gap of 3 to 4 minutes was provided between the two consecutive runs. Engine speed, brake power, torque, fuel consumption, BSFC and heat balance were measured during each run.

During the test, load on the engine was varied from 0 to 12 kg by adjusting the load knob provided on the control panel of the test rig. The tests were performed with pure diesel fuel and Neem Oil Methyl Ester (Biodiesel) blends (B-10, B-20, B-30).

### Formula Used:

$$\begin{aligned}
 \text{Torque (Kg - m)} &= \text{Load} \times \text{Arm length} \\
 \text{Brake Power (KW)} &= (2 \times \pi \times \text{Speed} \times \text{Torque} \times 9.81) / (60 \times 1000) \\
 \text{Brake Thermal Efficiency (\%)} &= \frac{\text{Brake power} \times 3600 \times 100}{\text{fuel flow} \frac{\text{kg}}{\text{hr}} \times \text{calorific value} \left( \frac{\text{kJ}}{\text{kg}} \right)}
 \end{aligned}$$

$$\text{Specific fuel consumption} \left( \frac{\text{kg}}{\text{kwh}} \right) = \frac{\text{Fuel flow} \frac{\text{kg}}{\text{hr}}}{\text{Brake power (KW)}}$$

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

$$\text{Specific energy consumption} \left( \frac{\text{MJ}}{\text{KW} - \text{hr}} \right) = \frac{\text{BSFC} \times \text{Calorific value}}{1000}$$

$$\text{Mechanical Efficiency (\%)} = \frac{\text{Brake power (kw)} \times 100}{\text{Indicated power (KW)}}$$

$$\text{Heat supplied by fuel} \left( \frac{\text{KJ}}{\text{h}} \right) = \text{fuel flow} \left( \frac{\text{kg}}{\text{h}} \right) \times \text{Calorific value} \left( \frac{\text{KJ}}{\text{kg}} \right)$$

$$\text{Heat equivalent to useful work} \left( \frac{\text{KJ}}{\text{h}} \right) = \text{Break power (KW)} \times 3600$$

$$\text{Heat brake power (\%)} = \frac{\text{Heat equivalent to useful work} \times 100}{\text{Heat supplied by fuel}}$$

## VI. RESULT AND DISCUSSION OF PERFORMANCE

### ➤ Brake Thermal Efficiency Vs Brake Power for diesel and NOME blends:

It is observed that BTHE for pure diesel and NOME increases with increase in load. It is also observed that Brake thermal efficiency increases with increase in percentage of biodiesel in the blend from B0 (pure diesel) to B20. BTHE observed is max for B20 blend. The reason for increase in BTHE is the presence of more oxygen in Biodiesel blend as compared to pure diesel. With further increase in percentage of biodiesel in the blend a slight decrease in BTHE is seen. The reason for the decrease in BTHE may be due to less volatility of biodiesel as compared to pure diesel. Variation of BTHE (%) with brake power is shown in Fig.3 for diesel and various NOME blends.

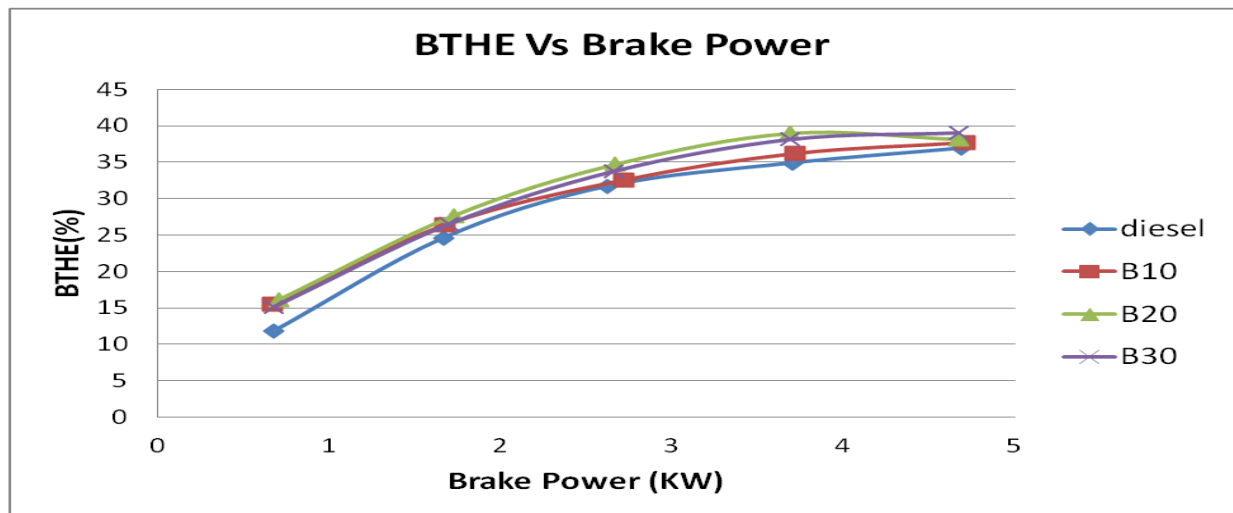


Fig.3. Brake thermal efficiency Vs Brake Power for diesel and NOME blends

### ➤ Exhaust Gas Temperature Vs brake power for diesel and NOME blends:

It is observed that exhaust gas temperature for pure diesel and various NOME blends increases with increase in load on the engine. It is also observed that exhaust gas temperature increases with increase in biodiesel percentage in the blend. This is due to more oxygen content in biodiesel and more efficient burning of fuel. The reason for rise in the exhaust gas

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

temperature may be due to larger ignition delay and increased quantity of fuel injected. The exhaust gas temperature can be reduced by adjusting the injection timing/injection pressure in to the diesel engine. Variation of exhaust gas temperature with brake power is shown in Fig.4 for diesel and various NOME blends.

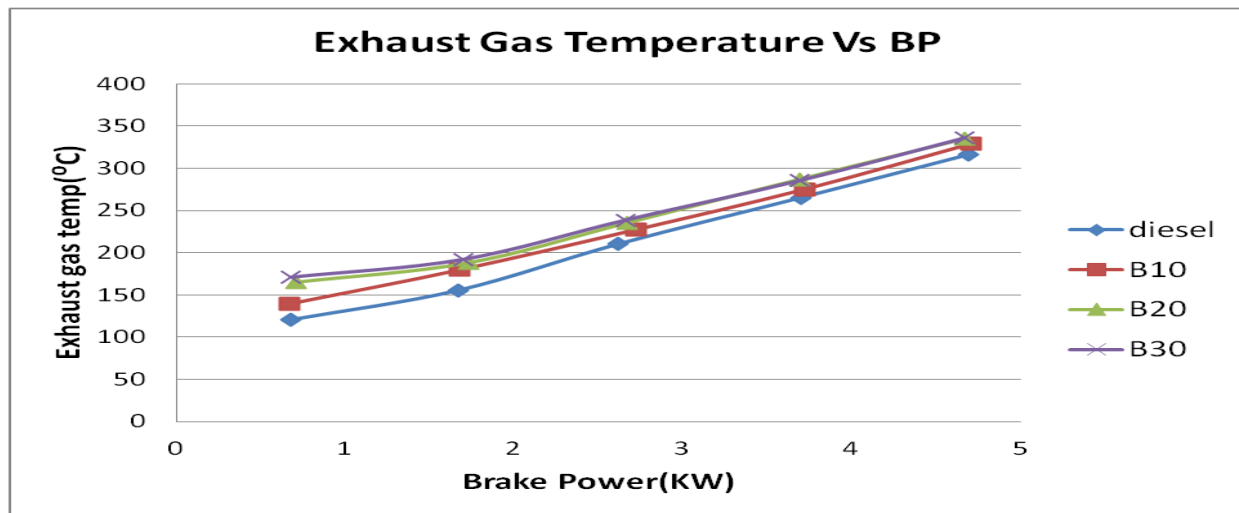


Fig.4. Exhaust Gas Temperature Vs Brake Power for diesel and NOME blends

### ➤ Brake Specific Fuel Consumption Vs brake power for diesel and NOME blends:

It is observed that Brake specific fuel consumption decreases with increase in load on the engine for pure diesel and NOME blended fuel. As the total fuel consumption increases with increase in biodiesel percentage in the blend because more fuel has to be inducted due to lower calorific value of biodiesel as compared to that of pure diesel. Thus BSFC increases with increase in biodiesel percentage in the blend. Variation of BSFC (Kg/KW-hr) with brake power is shown in Fig.5 for diesel and various NOME blends.

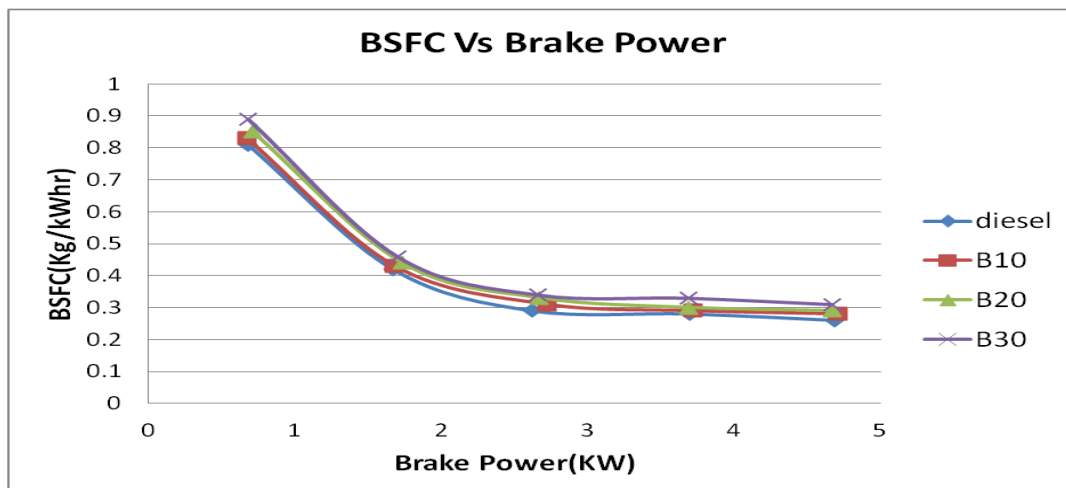


Fig.5. Brake Specific Fuel Consumption Vs Brake Power for diesel and NOME blends



# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

## ➤ Brake Specific Energy Consumption Vs brake power for diesel and NOME blends:

The trend for brake specific energy consumption is same as that of brake specific fuel consumption. Brake Specific Energy consumption decreases with increase in load on the engine. It is also observed that Brake specific energy consumption increases with increase in biodiesel percentage in the blend. Variation of BSEC with brake power is shown in Fig.6 for diesel and various NOME blends.

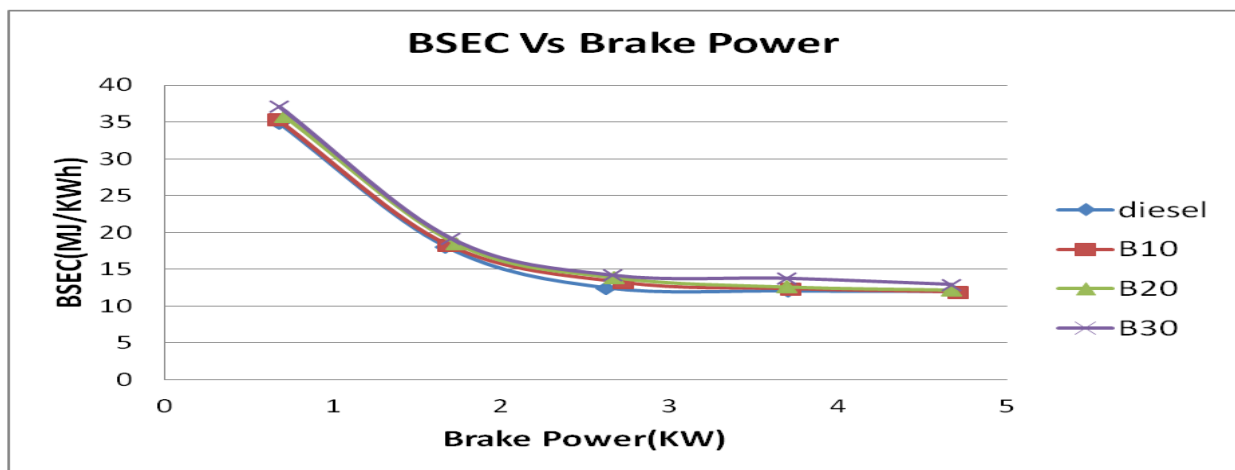


Fig.6. Brake Specific Energy Consumption Vs Brake Power for diesel and NOME blends

## VII. RESULT AND DISCUSSION OF EMISSIONS:

### ➤ CO Vs Brake Power for diesel and NOME blends:

Carbon mono oxide is one of the intermediate products formed during the combustion of hydrocarbons in the cylinder. It is observed that amount of CO produced decreases with increase in load on the engine for pure diesel and various blends of NOME, but at higher loads there is a steep increase in CO emission is observed. This may be due to less available time and lower A/F ratio (Richer mixture) for combustion of fuel at higher loads. It is also observed that amount of CO produced decreases with increase in percentage of biodiesel in the blend. The reason for this is oxygen content in the biodiesel which allows more carbon molecules to oxidize when a comparison is made to that of pure diesel. Variation of CO emission with brake power is shown in Fig.7 for diesel and various NOME blends.

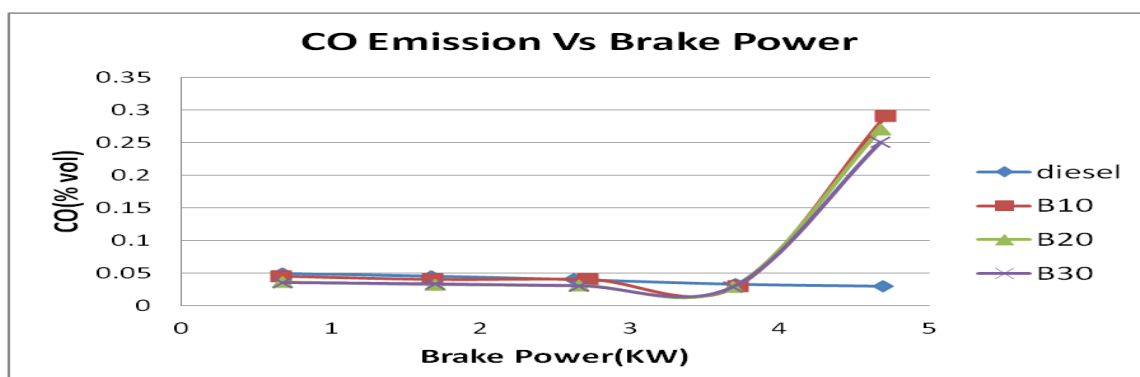


Fig.7 CO emission Vs Brake Power for diesel and NOME blends

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

### ➤ HC Vs Brake Power for diesel and NOME blends:

It is observed that HC emission increases as the load of the engine was increased for diesel and blends of NOME. The reason for this is increase in fuel consumption at high engine loads.

It is also observed that HC emission decreases with increase in percentage of biodiesel in the blend. The reason for this is availability of more oxygen due to presence of biodiesel. NOME biodiesel involves high oxygen content, which leads to more complete combustion with less HC emission. Variation of HC emission with brake power is shown in Fig.8 for diesel and various NOME blends.

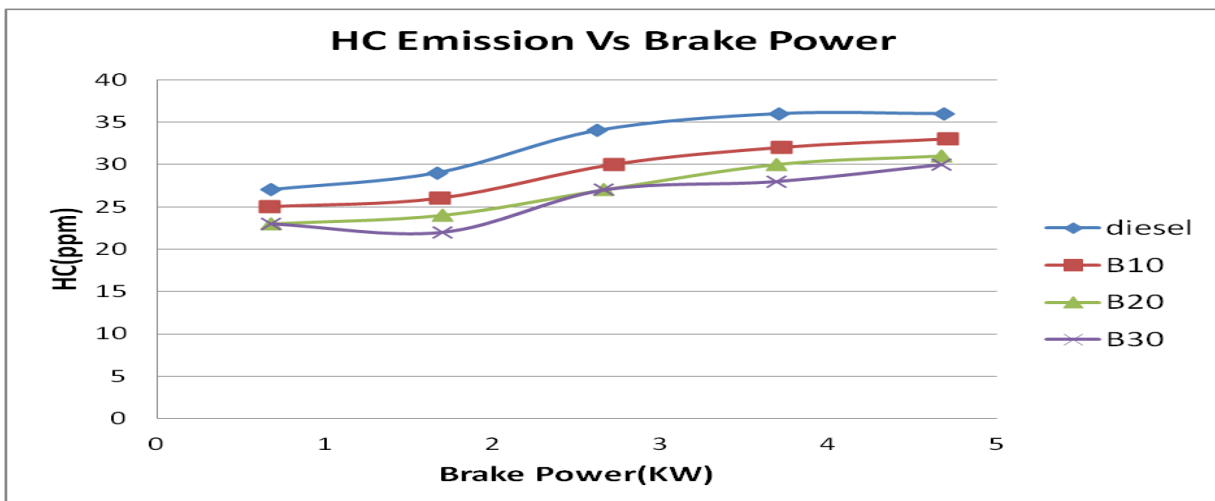


Fig.8. HC emission Vs Brake Power for diesel and NOME blends

### ➤ NOx Vs Brake Power for diesel and NOME blends:

The formation of oxides of nitrogen in the cylinder is affected by oxygen content, and combustion temperature. It is observed that NOx emission increases with increase in load on the engine. It is also observed that NOx formation for biodiesel blends is slightly higher than that of diesel fuel. This is due to the presence of oxygen in biodiesel which results in better combustion and causes higher temperature leading to higher NOx emission. Variation of NOx emission with brake power is shown in Fig.9 for diesel and various NOME blends.



## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

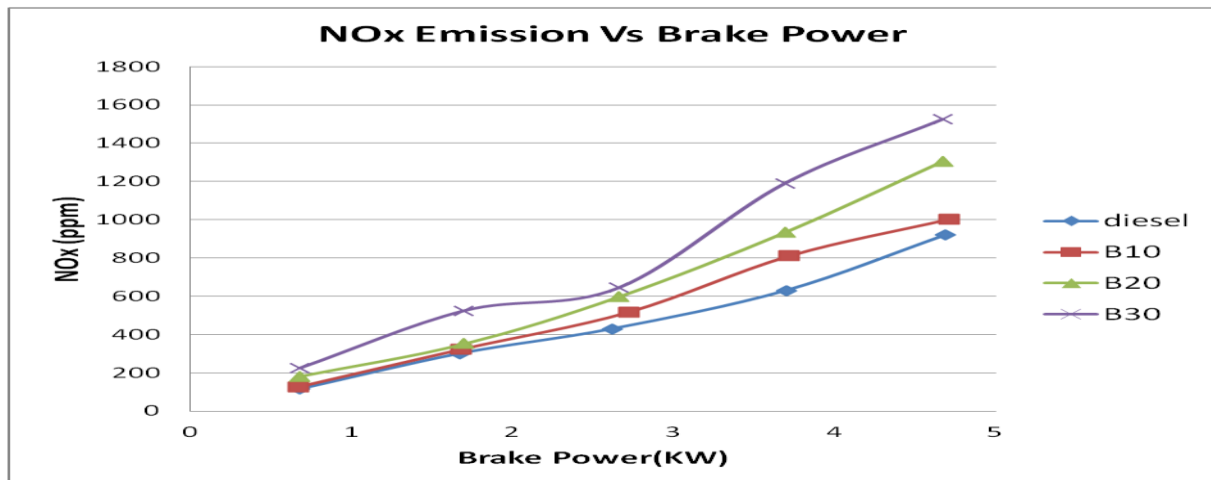


Fig.9. NOx emission Vs Brake Power for diesel and NOME blends

### ➤ Smoke Opacity Vs Brake Power for diesel and NOME blends:

It is observed that Opacity increases with increase in load on the engine. It is also observed that Opacity decreases with increase in biodiesel content in the blend.

At maximum load, the maximum value of opacity observed is for pure diesel and minimum value of opacity observed is for B30 NOME blend. At minimum load the maximum value of opacity observed is for pure diesel and minimum value of opacity is observed for B30 NOME blend.

The main reason for decrease in smoke with increase in bio-diesel percentage is that biodiesel is a sulphur free fuel. SO<sub>2</sub> is the major source for smoke formation. With the use of biodiesel in the blend, sulphur content decreases, hence smoke formation also decreases. Variation of Smoke Opacity with brake power is shown in Fig.10 for diesel and various NOME blends.

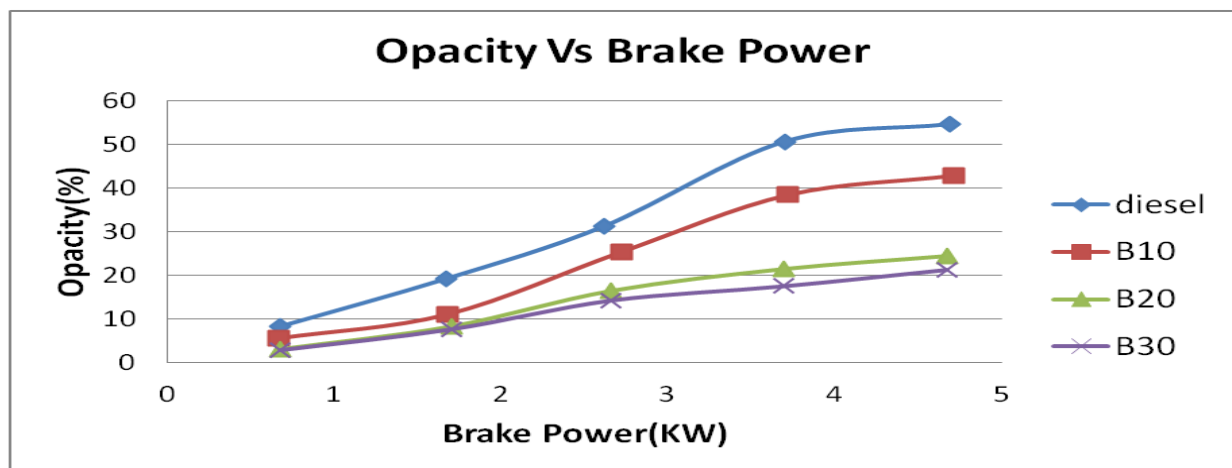


Fig.10. Opacity Vs Brake Power for diesel and NOME blends

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

## VIII. CONCLUSION & RECOMMENDATIONS:

### ➤ Conclusion

1. From the engine performance testing it can be concluded that the performance parameter and emission characteristics for Neem Oil Methyl Ester (biodiesel) have better results than that of pure diesel.
2. The BTHE increases proportionally with increase in brake power for lower and medium loads. This variation is due to better combustion with NOME blends as compared to pure diesel
3. BSFC also decreases with increase in brake power. The BSFC for NOME blends is slightly higher than that of pure diesel. BSEC also decreases with increase in brake power. The BSEC for NOME blends is slightly higher than that of pure diesel.
4. The BSEC curves obtained by B10, B20 and B30 are very similar to the pure diesel performed on the same engine.
5. The exhaust emissions from NOME (biodiesel) are lower than with regular diesel fuel.
6. The smoke opacity for B10, B20 and B30 blends of biodiesel at maximum brake power is significantly lower than the pure diesel's value.

Finally it can be concluded that Neem Oil Methyl Ester (biodiesel) is an industrially viable substitute for diesel engine.

### ➤ Recommendations

1. For long term use of biodiesel in an engine, high maintenance required is need to be investigated.
2. Viscosity for biodiesel as an issue which affects the performance, while using in a diesel based engine and can be reduced by increasing the injector pressure.
3. To reduce the viscosity of biodiesel preheated biodiesel can also be used for a diesel based engine, for which preheated system needed to be designed.
4. As the biodiesel fuel has excellent lubricating property, so either some modification is required in the fuel injector of the engine or some additive should be searched to make it easily viable for a diesel based engine.

## IX. ACKNOWLEDGEMENT

Author wish to acknowledge support rendered by Prof. (Dr.) R.S.Mishra, Head of Department of Mechanical Engineering at Delhi Technological University, New Delhi, in optimization of biodiesel yield using Taguchi Method and ANOVA and Dr. Amit Pal, Associate Professor of Mechanical Engineering at DTU, New Delhi, for allowing me to work in the Research Lab and I.C. Engine Lab at DTU, New Delhi. Author wish to thank Mr. Vijay Kumar, Lab Assistant at Research Lab, D.T.U., New Delhi, for his support to do the experimental works. Prof. (Dr.) R.S.Mishra suggestions and encouragement culminating to the writing of this manuscript.

## REFERENCES

- [1] Atul Dhar, Roblet Kevin, Avinash Kumar Agarwal, "Production of biodiesel from high-FFA neem oil and its performance, emission and combustion characterization in a single cylinder DIC engine", Fuel Processing Technology, Vol. 97, pp. 118-129, 2012.
- [2] Ayhan Demirbas, "Progress and recent trends in biodiesel fuels. Energy Conversion and Management", Vol. 50, pp. 14-34, 2009.
- [3] Dennis Y.C. Leung, Xuan Wu, M.K.H. Leung, "A review on biodiesel production using catalyzed transesterification", Applied Energy, Vol. 87, pp. 1083-1095, 2010.
- [4] E.F. Aransiola, E Betiku, DIO Ikhuomogbe and TV Ojumu, "Production of biodiesel from crude neem oil feedstock and its emissions from internal combustion engines", African Journal of Biotechnology, Vol. 11, pp. 6178-6186, 2012.
- [5] Freedman B, R. Butterfield and E. Pryde, "Transesterification kinetics of soybean oil", Journal of the American oil Chemists Society, Vol. 63, pp. 1375-80, 1986.
- [6] Fukuda H., A. Kondo and H. Noda, "Biodiesel fuel production by transesterification of oils", Journal of Bioscience and Bioengineering, Vol. 92, pp. 405-16, 2001.
- [7] GT Jeong, HS Yang, DH Park, "Optimization of transesterification of animal fat ester using response surface methodology", Bioresour. Technol, Vol. 100, pp. 25-30, 2009.

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

- [8] H Ibrahim, A. S. Ahmed, I.M. Bugaje, Dabo Mohammed, C. D. Ugwumma, "Synthesis of Bulk Calcium Oxide (Cao) Catalyst and its Efficacy for Biodiesel Production", Journal of Energy Technologies and Policy, Vol. 3, pp. 14-16, 2013.
- [9] Jon Von Gerpen, "Biodiesel processing and production", Fuel Process Technol, Vol. 86, pp. 1097-1107, 2005.
- [10] J.M. Marchetti, A.F Errazu, "Esterification of free fatty acids using sulfuric acid as catalyst in the presence of triglycerides", Biomass. Bioenerg., Vol. 32, pp. 892-895, 2008.
- [11] L.C. Meher, D. Vidya Sagar, S.N. Naik, "Technical aspects of biodiesel production by transesterification – a review", Renew. Sustain. Energy, Vol. 10, pp. 248-268, 2006.
- [12] Madhu Agarwal, Kailash Singh, Ushant Upadhyaya and S P Chaurasia, "Potential vegetable oils of Indian origin as biodiesel feedstock – An experimental study", Journal of Scientific & Industrial Research, Vol. 71, pp. 285-289, 2012.
- [13] M. A. Hanna, Loren Isom and John Campbell, "Biodiesel; Current perspectives and future", Journal of Scientific & Industrial Research, Vol. 64, pp. 854-857, 2005.
- [14] Md. Hasan Alia, Mohammad Mashud, Md. Rowsonazzaman Rubel, Rakibul Hossain Ahmad, "Biodiesel from Neem oil as an alternative fuel for Diesel engine", Procedia Engineering, Vol. 56, pp. 625 – 630, 2013.
- [15] M.A. Fazal, A.S.M.A. Haseeb and H.H. Masjuki, "Biodiesel feasibility study: An evaluation of material compatibility; performance; emission and engine durability", Renew. Sustain. Energy Reviews, Vol.15, pp. 1314-1324, 2011.
- [16] Muthu, V. SathyaSelvabala, T. K. Varathachary, D. Kirupha Selvaraj, J. Nandagopal and S. Subramanian, "Synthesis of biodiesel from neem oil using sulfated zirconia via transesterification", Brazilian Journal of chemical Engineering, Vol. 27, pp. 601-608, 2010.
- [17] Nielsen P. M., J. Brask and Fjerbaek, "Enzymatic biodiesel production: Technical and economical considerations", European Journal of Lipid Science, Vol. 110, pp. 692-700, 2008.
- [18] Olugbenga Olufemi Awolu and Stephen Kolawole Layokun, "Optimization of two-step transesterification production of biodiesel from neem (Azadirachta indica) oil", International Journal of Energy and Environmental Engineering, Vol. 4, pp. 1-9, 2013.
- [19] Rahul D.Gorle, Diwesh B.Meshram, Pratik L.Naik, Vivek S.Narnaware, "Optimization of effective parameter of Jatropha Biodiesel using Taguchi Method and performance analysis using CI Engine", International Journal of Innovative Technology and Exploring Engineering (IJITEE), Vol.3, pp.46-52, 2013.
- [20] R. S. Mishra, Amit Pal, Anand Prakash Mall, "Effect of Homogeneous Catalysts on Production of Biodiesel from Crude Neem Oil Feedstock and Cost Analysis of Biodiesel Production", International Journal of Advance Research and Innovation, Vol.3, pp.503-507, 2015.
- [21] R. S. Mishra, Amit Pal, Anand Prakash Mall, "Application of Taguchi Experimental Design for the Optimization of Effective Parameters on the Neem oil Methyl Ester (Biodiesel) Production", International Journal of Advance Research and Innovation, Vol.3, pp.490-497, 2015.

### BIOGRAPHY



Anand Prakash Mall is a M.Tech. (Thermal) Scholar at Department of Mechanical Engineering, Delhi Technological University, New Delhi-110042, India. His area of Specialization are Biodiesel Production, Material Science