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EXPERIMENTAL INVESTIGATION TO MITIGATE EXHAUST EMISSIONS IN A SINGLE CYLINDER CI ENGINE FUELLED WITH METHYL ESTER OF NEEM OIL USING α TOCOPHEROL ACETATE

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ABSTRACT

Biodiesel offers cleaner combustion over conventional diesel fuel including reduced particulate matter, carbon monoxide and unburned hydrocarbon emissions. However, several studies reported slight increase in NO_x emissions (about 13%) for biodiesel fuel compared with conventional diesel fuel. Use of antioxidant additives is one of the most cost-effective ways to reduce the formation of NO_x. In this study, the effect of antioxidant additive (α-Tocopherol Acetate) on NO_x emissions in a neem methyl ester fuelled direct injection diesel engine has been investigated experimentally. The antioxidant additive is mixed in various proportions with neem methyl ester and was tested in computerized 4-stroke water-cooled single cylinder diesel engine of 3.5 kW rated power. Results show that the antioxidant additive is effective in controlling the emissions like NO_x, HC and Smoke intensity of neem biodiesel fuelled diesel engines. Particularly for MENO200T mixture, NO_x emissions reduce by 22.41 % at full load conditions due to the delay or inhibitions of oxidative process by donating an electron or hydrogen atom to a radical derivative.

Keywords: Biodiesel, Neem, α Tocopherol Acetate, Antioxidants, Fuel additives and Emissions.

INTRODUCTION

Biodiesel is one of the best substitutes to the fossil diesel fuel today in the world. Biodiesel production and demand has been growing fast and will continue to do so (Demirbas, 2007 and Aninidita Karmakar *et al.,* 2010). The main global warming pollutant carbon dioxide problem is not in biodiesel. Vegetable oil plants in nature itself absorbs carbon dioxide thereby compensates the CO_2 emissions, which are emitted during its usage as biodiesel fuel. While growing the plants absorb the carbon dioxide. When burnt, biodiesel emits the same amount of CO_2 as the plants absorb in growth and hence no greenhouse effect and global warming. For pure 100 % biodiesel, NO_x increases by 13 % more than (Demirbas, 2009 and Soo-Young, 2011) petrodiesel. NO_x is a major cause of smog, ground level ozone and also a cause of acid rain. As the use of biodiesel has increased tremendously, the rise in NO_x emissions could become a significant barrier to market expansion. The development of improved NO_x reduction technologies is therefore of critical importance to the global environment (Jinlin Xuea *et al.,* 2011). NO_x is generated during combustion by three mechanisms: thermal, prompt, and fuel. High combustion temperature (1700 K) breaks the strong triple bond of nitrogen molecules and form highly reactive atomic nitrogen, which reacts with oxygen and generates thermal NO_x. According to prompt mechanism, formation of free radicals in the flame front of hydrocarbon flames leads to rapid production of NO_x. The fuel NO_x is formed by the reaction of nitrogen bound in the fuel with oxygen during combustion (Varatharajan *et al.,* 2011).

Thermal and prompt NO_x are the dominant mechanisms in biodiesel-fuelled engines since; biodiesel does not contain fuel-bound nitrogen. Thermal mechanism is largely unaffected by fuel chemistry, where as prompt mechanism is sensitive to free radical concentrations within the reaction zone. The free radicals formation during combustion determines the rate of reaction and prompt NO_x production. Free radical is a highly reactive molecule with one or more unpaired electrons. Examples include oxygen molecule, nitric oxide, superoxide ion and hydroxyl radical. Antioxidant delays or inhibits oxidative processes by donating an electron or hydrogen atom to a radical derivative. In this study, methyl ester of neem oil (MENO) was used as a test fuel and α-Tocopherol Acetate as antioxidant was selected as an additive. This paper, presents our investigation on the effect of antioxidant on emissions of a neem derived biodiesel fuelled direct injection diesel engine.

EXPERIMENT SETUP

Experiments were carried out in a single cylinder, water-cooled, naturally aspirated direct injection diesel engine of 3.5 kW rated power coupled with an eddy current dynamometer, Figure 1. The specifications of the diesel engine are shown in Table 1. An eddy current dynamometer coupled to the engine was used as a loading device. The fuel flow rate, speed, load, exhaust gas temperature and gas flow rate were displayed on a personal computer. Exhaust emissions were measured with AVL DiGas 444 gas analyser. α-Tocopherol Acetate was accurately weighed using high precision electronic weighing balance and added to measured quantity of neem biodiesel. To make 0.010%-m of

antioxidant mixture 100 mg of antioxidant was added to 1 kg of biodiesel. A 3000-rpm speed mixer was used to prepare a homogeneous mixture of antioxidant and fuel. The effects of antioxidant additive on NO_x, CO, CO_2, HC and smoke emissions of neem methyl ester fuelled diesel engine were systematically investigated experimentally in this study. The cooling water flow rate and temperature at the inlet was maintained at 0.083 kg/s and 29°C respectively. Experiments were carried out after thorough inspection of the engine and calibration of measuring instruments. The same test procedure and practice were followed for all the test fuel mixtures. The emissions from the engines were studied at different antioxidant mixtures 0.010 %-m (MENO100T), 0.020 %-m (MENO200T), 0.030 %-m (MENO300T) with a mean engine speed of 1500 rpm. The effects of antioxidants addition on NO_x, HC, CO_2 and smoke emissions in a neem methyl ester fuelled DI diesel engine at different loads have been studied in this investigation.

TEST FUELS

Neem oil is light to dark brown in colour, bitter in taste and has a strong odour. Neem oil can be obtained from solvent extraction of the neem seed, fruit, oilcake or kernel. A large industry in India extracts the oil remaining in the seed cake using hexane. The neem tree is native to India and Burma and almost the whole tree is usable for various purposes such as medicines, pesticides and organic fertilizer. Neem can be grown on very marginal soils that may be very rocky, shallow, dry, or pan forming. Neem tree can tolerate some extreme conditions like temperature of 45°C and rainfall less than 35 cm per year (Ragit *et al.*, 2011). Neem tree get full maturity in just 10 years and gives an average seed yield of around 5.25 tonnes per hectare. The percentage oil yield and oil extraction efficiency for neem oil are 28% and 94% respectively. As the energy ratio of neem biodiesel is around 1.64, it is considered as one of the best renewable fuels in view of environmental inputs (Yadav *et al.,* 2010). Azadirachtin is the main constituent of neem seed oil, which varies from 300 to 2500 ppm depending on the extraction technology and quality of the neem seeds crushed. The oil contains sulfurous compounds, which gives it a pungent odour and a less clean burn than other vegetable oils. It comprises of Triglyceride and Triterpenoid compounds. Neem Oil is gives average yield of around 4 tonnes per hectare and has oil content of 45%.

Transesterification: Initially the neem oil and methyl alcohol is mixed in 6:1 molar proportion and heated to about 55°C and then this combination was mixed with 2% NaOH and maintained at 60°C for 60 min (Barnwal and Sharma, 2005). Then it is allowed to settle by gravity for 24 h (Knothe, 2010 and Ragit et al., 2011). Thus the methyl ester of neem oil termed as biodiesel was produced. The esterified neem oil contains a little amount of water, which was removed by heating the oil before using in the engine. The higher percentage of esters alkanes and absence of phosphorous and sulphur make this esterified non-edible neem oil, the future candidate for alternative environment-friendly diesel fuel (Kumar and Sharma, 2011). The measured properties of diesel fuel, neem oil and methyl ester of neem (Banapurmath et al., 2009) were given in Table 2. The performance parameters like brake thermal efficiency and brake specific fuel consumption, and emission parameters like HC, CO, CO_2, NO_x, and Smoke emissions are measured for diesel fuel, MENO and MENO - α - Tocopherol Acetate mixtures. The emission results at various ratios of mixtures are compared experimentally.

RESULTS AND DISCUSSION

The effect of antioxidant additives on NO_x, HC, CO_2, CO and smoke intensity with methyl ester of neem oil were systematically investigated in this experimental study. The emission and performance measurements were taken repeatedly for 5 times with separate engine run. The analysis is done for the average of the readings.

Emission characteristics

Comparison of NO_x emissions: Figure 2, shows the variation of NO_x with brake power. The results show that NO_x emission increases with the increase of engine load. Addition of antioxidant decreases NO_x emission compared to pure biodiesel fuel. The NO_x concentration decreases with the increase of antioxidant fraction, up to MENO200T mixture then it decreases. It is found that MENO200T reduces NO_x emission by 22.41 % compared to pure biodiesel at full load.

Comparison of HC emissions: Figure 3, indicates the variation of hydrocarbon emission with brake power. α-Tocopherol Acetate is a reducing agent which can reduces the functional groups present in the azadirachtin. So the hydrocarbon emission is found to be lower with the addition of antioxidant fraction with the oil. MENO100T mixture reduces HC emission by 48.81 % at full load condition. In general also all antioxidant mixture reduces HC compared to pure biodiesel.

Comparison of CO_2 emissions: Figure 4, shows the variation of carbon dioxide emission with brake power. All neem-antioxidant mixtures slightly decrease the CO_2 emissions. There is no significant variation in carbon dioxide emissions with the addition of antioxidant mixtures at full load conditions.

Comparison of CO emissions: CO emissions are the products of incomplete combustion and primarily depend on the fuel air equivalence ratio. Figure 5, shows the variation of carbon monoxide with brake power. All CO emissions at full load

conditions were slightly lower than pure biodiesel fuel. There is no significant variation in CO emissions with the addition of antioxidant mixtures.

Comparison of smoke intensity: Figure 6, shows the variation of smoke intensity with brake power for diesel and biodiesel-antioxidant mixtures. Addition of antioxidant decreases the smoke at all load conditions. The MENO200T mixture decreases smoke intensity by 9.59 % compared to pure diesel at full load conditions.

Performance characteristics

Comparison of brake thermal efficiency: Figure 7, shows the variation of thermal efficiency with brake power for biodiesel-antioxidant mixtures. The brake thermal efficiency for diesel fuel is also shown for reference. The brake thermal efficiency is lower for MENO at all loads when compared with diesel fuel. The brake thermal efficiency slightly increases with addition of antioxidant mixtures.

Comparison of brake specific fuel consumption: Figure 8, shows the variation of brake specific fuel consumption with brake power for diesel fuel, biodiesel and biodiesel-antioxidant mixtures. It is observed that the brake specific fuel consumption decreases with load for all biodiesel mixtures. Initially BSFC slightly decreases with the addition of antioxidant mixtures. There is no significant variation in BSFC with the addition of antioxidant mixtures.

CONCLUSIONS

The performance and emission characteristics of pure diesel, MENO and MENO-α Tocopherol Acetate mixtures were analyzed and compared. Based on the experimental results, the following conclusions are drawn.

1. For MENO200T mixture, NO_x emissions reduce by 22.41 % compared to pure biodiesel at full load conditions.
2. For MENO100T mixture, HC emissions reduce by 48.81 % compared to pure biodiesel at full load conditions.
3. For MENO200T mixture, Smoke Intensity reduces by 9.59 % compared to pure biodiesel at full load conditions.
4. There is no significant variation in CO, CO_2 emissions, BTE and BSFC.

Based on the present experimental analysis, antioxidant (α-Tocopherol Acetate) addition with neem biodiesel reduces NO_x, HC and smoke intensity.

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REFERENCES

Aninidita Karmakar, Subrata Karmakar, A and B., Souti Mukherjee. 2010. Properties of various plants and animals feedstock for biodiesel production. *Bioresource Technology,* 101:7201–7210.

Banapurmath, N. R., Tewari, P. G., Yaliwal, V.S., Satish Kambalimath, Y.H and Y.H. Basavarajappa. 2009. Combustion characteristics of a 4-stroke CI engine operated on Honge oil, Neem and Rice Bran oils when directly injected and dual fuelled with producer gas induction. *Renewable Energy,* 34: 1877–1884.

Barnwal, B. K and M.P. Sharma. 2005. Prospects of biodiesel production from vegetable oils in India. *Renewable and Sustainable Energy Reviews, 9:* 363–378.

Demirbas, A. 2007. Importance of biodiesel as transportation fuel. *Energy Policy, 35:* 4661–4670.

Demirbas, A. 2009. Progress and recent trends in biodiesel fuels. *Energy Conversion and Management, 50:*14–34.

Jinlin Xuea. , Tony E. Grift. , Alan C Hansena. 2011. Effect of biodiesel on engine performances and emissions. *Renewable and Sustainable Energy Reviews, 15: 1098*–1116.

Knothe, G. 2010. Biodiesel and renewable diesel: A comparison. *Progress in Energy and Combustion Science, 36:* 364–373.

Kumar, A., Sharma, S. 2011. Potential non-edible oil resources as biodiesel feedstock: An Indian perspective. *Renewable and Sustainable Energy Reviews, 15:* 1791–1800.

Ragit, S. S., Mohapatra, S. K., Kundu, K., Prashant Gill. 2011. Optimization of Neem methyl ester from transesterification process and fuel characterization as a diesel substitute. *Biomass and Bioenergy, 35:* 1138-1144.

Soo-Young, No. 2011. Inedible vegetable oils and their derivatives for alternative diesel fuels in CI engines: A review. *Renewable and Sustainable Energy Reviews, 15:*131–149.

Varatharajan, K., Cheralathan, M., Velraj, R. 2011. Mitigation of NOx emissions from a jatropha biodiesel fuelled DI diesel engine using antioxidant additives. *Fuel, 90:* 2721-2725.

Yadav, A., Singh, O., Kumar, N. 2010. Evaluation of Energy Ratios for Karanja and Neem Biodiesel Life cycles. *SAMRIDDHI-A Journal of Physical Sciences, Engineering and Technology, 1:*55 – 59.

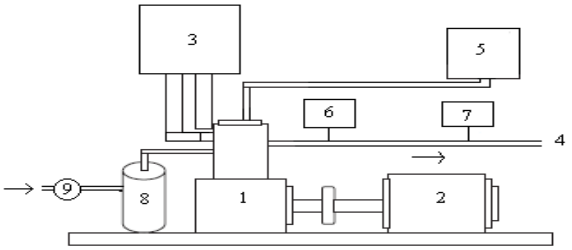
Table 1 Specifications of engine

Make & Model	Kirloskar & TV1
Power	3.5 KW @ 1500 rpm
Type	Multi Fuel
Speed	1500 rpm
Compression ratio	12:1 to 18:1
Bore	87.5 mm
Stroke	110 mm
Injection Variation	0-25 Deg BTDC
Capacity	661 cc
Method of loading	Electrical load
Method of cooling	Water
Type of ignition	Compression ignition

Table 2. Comparison of Diesel, Neem Oil and MENO

Property	Diesel	Neem Oil	MENO
Density (g/cm³)	0.8359	0.944	0.890
Net calorific value (kJ/kg)	44500	35435	36080
Kinematic viscosity	2-3	38.2	6.64
Flash point (°C)	75	201	180
Cetane number	51	55	53

Figure 1 Engine and Data Acquisition System



1. Engine
2. Eddy Current Dynamometer
3. Fuel Tank
4. Exhaust Pipe
5. Data Aquisition System
6. Gas Analyser
7. Smoke Gun
8. Surge Tank
9. Air Flow Meter

Figure 2 Variation of NO_x with Brake Power

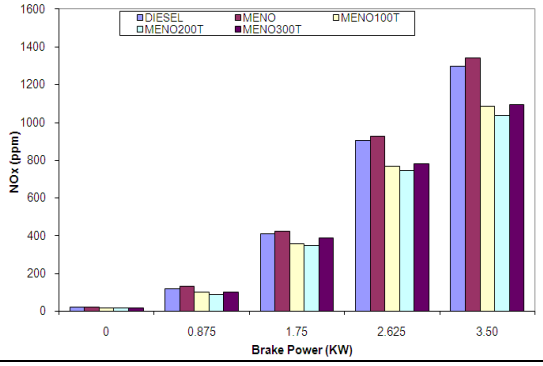


Figure 3 Variation of Hydrocarbon with Brake Power

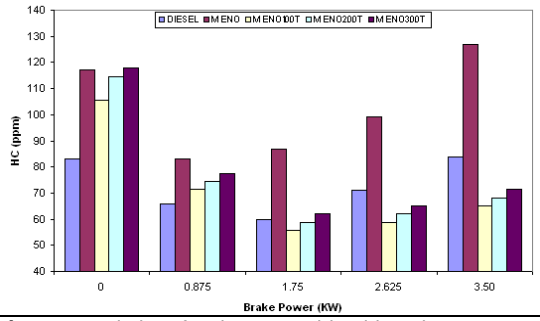


Figure 4 Variation of Carbon dioxide with Brake Power

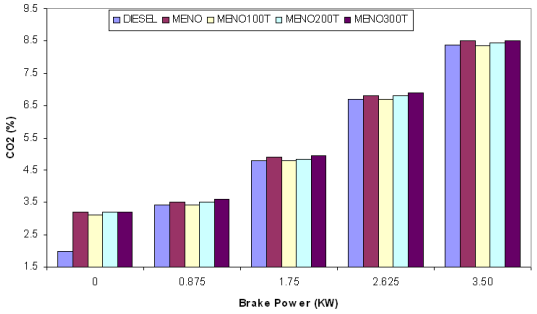


Figure 5 Variation of Carbon monoxide with Brake Power

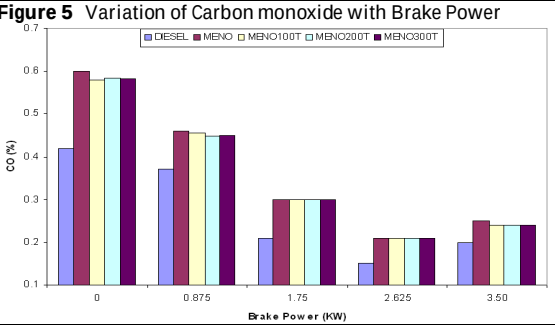


Figure 6 Variation of Smoke intensity with Brake Power

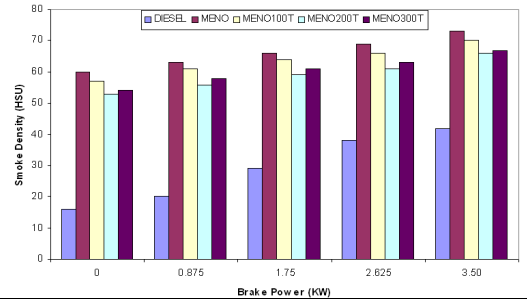


Figure 7 Variation of Brake Thermal efficiency with Brake Power

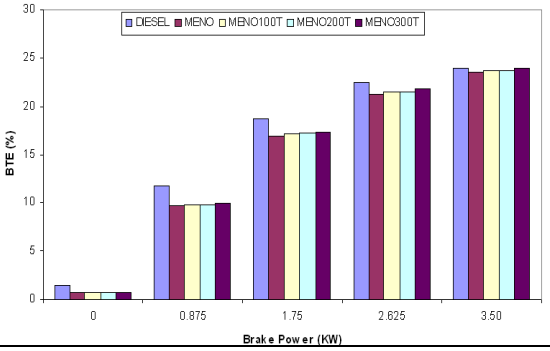
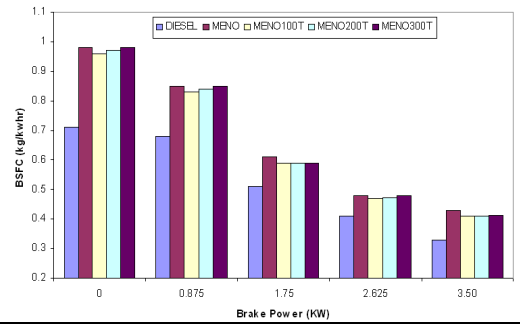


Figure 8 Variation of Brake Specific Fuel Consumption with Brake Power



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