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Evaluation of Neem Oil Biodiesel with 2-Ethyl Hexyl Nitrate (2-EHN) as Cetane Improver on Performance and Emission Characteristics of a DI Diesel Engine

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Abstract- **In the present experimental investigation, an effect of cetane improver ethyl hexyl nitrate (EHN)as additive has been made to study the diesel engine performance, emission and combustion characteristics usingneem oil biodiesel. The engine test was carried out in a single cylinder, direct injection, air cooled, and naturally aspirated diesel engine. The test results showed a reduction of Brake specific fuel consumption (BSFC) with an increase in Brake thermal efficiency (BTE). In the case of emission analysis, the reduction of CO, HC and smoke emissions are observed with an increase in NOx emission. Therefore, EHN as cetane improver can be used in a direct injection diesel engine fuelled by neem oil biodiesel without any engine modifications.**

I. INTRODUCTION

The use of cetane improvers as additive in diesel engines has been subject to many investigation, such as improvement for engine performance and emission characteristics. Cetane number is a measurement of the combustion quality of a fuel in diesel engines. It is a fuel's ignition delay measurement. The ignition delay period is the time period between start of fuel injection and the beginning of the combustion process. cetane improvers are used to improve the combustion characteristics, reducing ignition delay and burning point. The main effect of additives is to initiate early formation of radical elements which provides an efficient mechanism for hydroxyl formation. Generally, cetane additives are used in diesel engines for controlling emission gases. Manycetane improvers are used widely, such as alkyl nitrate, perioxide compounds, methyl oleate, Ethyl hexyl nitrate (EHN) and di-methylpropate or neopentane.The worldwide production of EHN is estimated to be about 100,000 tons per year. Moreover, cetane improvers can be classified as perioxides, nitrites, nitroso-carbamates, tetra-azoles and thio-aldehydes. The addition of EHN additive as cetane improver increases NO_x emission in a premixed diesel combustion mode. The formation of NO_x emission is due to the decomposition of the 2-EHN additive.

Zhang et al.[1] have done investigation using dimethylfuran (DMF) as additive with 2% EN addition. The test results showed that ignition delay reduced with EN addition and the cylinder pressure has decreased linearly with the increasing ratio of EN additive. In the case of emission gases, NO_x emission increased with a considerable decrease in CO, HC and smoke emissions. Sathiyamoorthi et al [2] have investigated the effect of antioxidant additives such as BHA and BHT using lemongrass oil as fuel in diesel engine. The NO_xemission was decreased by 11% than LGO25 without any additive. Li et al [3] have examined the effect of three different cetane improvers such as EHN, Cyclohexyl nitrate and 2-methoxyethyl ether using methanol/biodiesel blend. The test results showed than an increase in HC and CO concentrations with a reduction of NOx emission. The current study focuses on the engine performance and emission characteristics of a DI diesel engine using EHN as cetane improver. In this study, the effects of EHN addition in different ratios (2.5% and 5% by volume) to neem oil biodiesel (B20) are investigated and compared to standard diesel fuel.

II. TEST FUEL: NEEM OIL BIODIESEL

Generally, biodiesel is produced by trans esterification process using NaOH or KOH as catalyst. The figure.1 shows the detailed conversion process neem oil into neem oil methyl ester by the trans esterification process. In this process, 800 ml of neem oil, 200 ml of methanol and 2 gram of NaOH were taken in the beaker and stirred well till the formation of ester. This mixture was heated to 80°C and then allowed for 12 hours. There are two layers formation, the bottom layer consists of glycerol and top layer of ester.

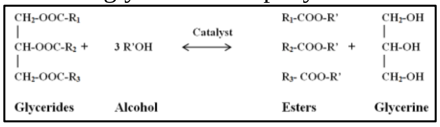

Figure.1 Trans esterification of Neem oil biodiesel

III. EHN (2-ETHYLHEXYL NITRATE)

The main advantages of using cetane improver (EHN) are improved cold weather starting, reduced fuel consumption, reduced emissions, improved engine durability, reduced engine noise and knocking and reduced warm-up time. EHN is also known as iso-octyl nitrate (ION) which used to improve fuel ignitability in diesel engines. EHN is a nitrate compound, and stable at room temperature conditions. The kinetics of its decomposition reaction provides very slow reaction rates at temperatures below 100°C. Table 1 shows the important properties of EHN –cetane improver. Figure 2

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shows the chemical structure of EHN additive. Table 2 shows the properties of diesel, neem oil with EHN additive. In this study, neem oil methyl ester 20% by volume, diesel fuel 77.5% by volume and EHN 2.5% by volume are taken as B20+EHN2.5% fuel blend. The B20+EHN5% fuel blend consists of neem oil methyl ester 20% by volume, diesel 75% and EHN 5% by volume.

TABLE.1 PROPERTIES OF EHN

Molecular formula	Molecular weight	CAS Nr	EINECS Nr	Density at 15°C (kg/l)	Alcohol content
$C_8H_{17}NO_3$	175.23	27247-96-7	248-363-6	0.967	≤0.5%

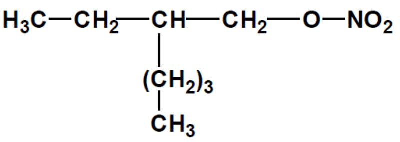


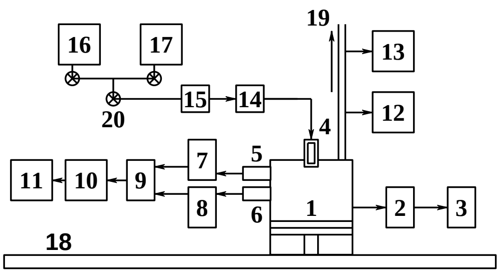
Figure.2 Chemical structure of EHN

TABLE.2
PROPERTIES OF DIESEL AND NEEM OIL AND ITS BIODIESEL

Properties	Diesel	Neem Oil	BN20	B20+EHN2.5%	B20+EHN5%
Kinematic Viscosity (Cst) at 40°C	3.12	6.77	3.74	3.74	3.74
Density (kg/m^3)	825	875	828	828	828
Flash Point (°C)	53	172	65	65	65
Calorific value (MJ/kg)	43.57	36.5	41.9	41.94	41.94
Cetane Number	45-55	31	43.5	46	50

IV. EXPERIMENTAL SET-UP AND PROCEDURE

A single cylinder diesel engine was used to conduct experiments. It is a vertical, naturally aspirated and air cooled engine. The detail specifications of the engine are summarized in Table.3. An electrical dynamometer was used to apply load on the engine. The standard injection pressure of 200 bar and standard injection timing of 23°bTDC was set. The air flow was measured by using an orifice meter attached with an air damping tank. The fuel consumption was measured by a burette and a stop watch for 10 cc of fuel consumption. An AVL pressure transducer was used to measure the in-cylinder pressure and AVL 365C angle encoder was used to measure the speed of the engine. An AVL Digas 444 analyzer and was used to measure the emission gases such as CO, CO_2, NO_x, HC and O_2 gases. Smoke is measured by using AVL smoke meter [7].



1)Diesel Engine 2) Electrical Dynamometer 3) Electrical Loading Unit 4) Fuel Injector 5) TDC pickup sensor 6) Pressure pickup sensor 7) Charge Amplifier 8) TDC Amplifier 9) Digital Data Acquisition System 10) Computer 11) Printer 12) Five gas analyser 13) AVL smoke meter 14) Fuel pump 15) Fuel filter 16) Diesel Tank 17) Biodiesel Tank 18) Engine Bed 19) Exhaust Gas 20) Control valve

Figure3. Schematic diagram for Engine Setup

TABLE.3
TEST ENGINE SPECIFICATIONS

Model	Kirloskar TAF 1
Type	Single Cylinder, 4-stroke, Direct Injection
Power	4.4 kW
Bore	87.5 mm
Stroke	110 mm
Cubic capacity	0.553 Litres
Compression ratio	17.5:1
Rated speed	1500 rpm
Cooling type	Air cooling
No. of holes	3
Nozzle hole diameter	0.25 mm
Fuel injection timing	23˚ bTDC

V. RESULTS AND DISCUSSION

a. *Performance Characteristics*

i. BRAKE SPECIFIC FUEL CONSUMPTION (BSFC)

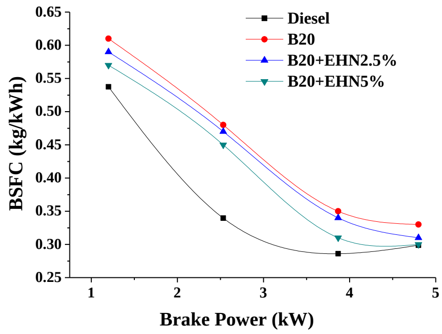


Figure 4 Variation of BSFC with Brake power for Neem oil methyl ester with EHN

It is observed from figure 4 that brake specific fuel consumption increased with the biodiesel blends by 9.46% than diesel. It is due to the lower calorific value of the biodiesel blend [6]. BSFC decreases by 6.06% and 9.1% at B20+EHN2.5% and B20+EHN5% fuel blends respectively than B20 fuel blend. The addition of EHN additive to the biodiesel blend helps to increase the fuel vapour diffusion rate. Moreover, the better air-fuel mixture formulation into the combustion chamber is also achieved through the addition of EHN additive. The higher cetanenumber of EHN contributes the reduction of ignition timing which results in development in the combustion attributes [2, 4].

ii. BRAKE THERMAL EFFICIENCY (BTE)

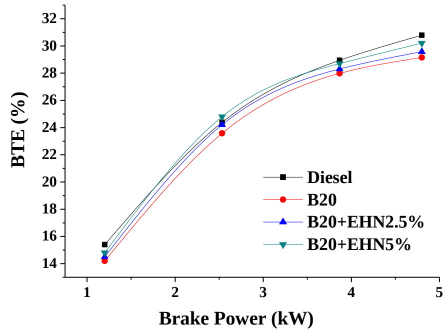


Figure 5 Variation of BTE with Brake power for Neem oil methyl ester with EHN

The BTE for neem oil biodiesel with EHN additive is shown in figure 5. The BTE for neem oil methyl ester decreased when compared to diesel. The reason is lower calorific value and higher viscosity of the biodiesel blend. The addition of EHN to biodiesel blends, BTE increased when compared to B20 fuel blend but still the decrease in BTE is noted than diesel. BTE is decreased by 3.9% and 1.9% at B20+EHN2.5% and B20+EHN5% fuel blends respectively than diesel fuel. Moreover, the amount of oxygen contents in the biodiesel blends improvesatomization efficiency which promotes the combustion phenomena with the help of EHN additive [3].

b. Emission characteristics

i. CO emission

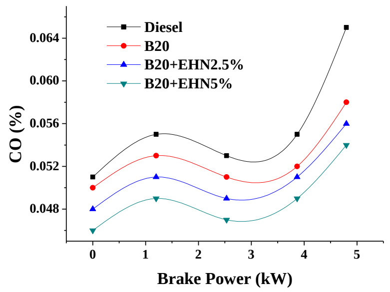


Figure 6 Variation of CO emission with Brake power for Neem oil methyl ester with EHN

CO emission with EHN blended Neem oil methyl ester is shown in figure 6. CO emission decreases for bioidesl blend than diesel. The main reason for the reduction of CO emission for biodiesel blends is the better combustion process with the availability of oxygen content. The CO emission decreases by 9.7% and 14.6% at B20+EHN2.5% and B20+EHN5% respectively than diesel. During the oxidation of CO to CO2, heat is observed from the combustion chamber; hydrogen peroxide (H_2O_2) as well as peroxyl (H_2O) are formed and converted promptly into elements of hydroxyl. As a result, CO is converted into CO_2.

ii. HC emission

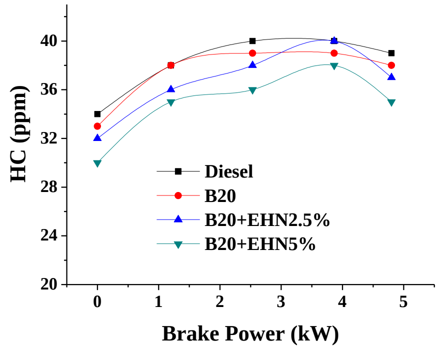


Figure 7 Variation of HC emission with Brake power for Neem oil methyl ester with EHN

The HC emission for various blends of neem oil biodiesel with EHN additive is shown in figure 7. HC emission decreases by 7.3% for neem oil biodiesel blend when compared to diesel. It is mainly due to the availability of oxygen content in the biodiesel which influences the oxidation unburnt hydrocarbon particles thus results in lower HC emission [5].The HC emission decreases by 9.7% and 14.6% for B20+EHN2.5% and B20+EHN5% respectively when compared to diesel. On the other hand, cetane number and the air-fuel acceleration are improved by the addition of EHN additive which reduces the premixed combustion rate with the larger diffusion combustion period.

iii. NO_x emission

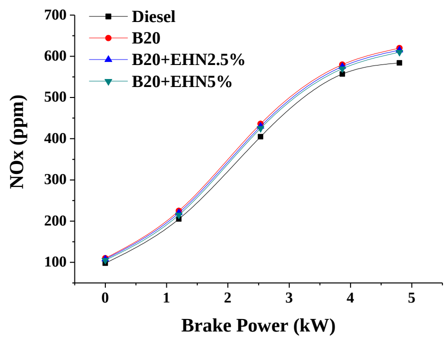


Figure 8 Variation of NO_xemission with Brake power for Neem oil methyl ester with EHN

Figure 8 shows the variation of NO_x emission with brake power for various blends of EHN additives. NO_x emission increases by 5.8% for neem oil methyl ester when compared to diesel fuel. From the figure, it is observed that NO_x emission slightly decreases for EHN added biodiesel blends when compared to B20 fuel blend. But it is higher than that of NO_x emission of diesel fuel. NO_x emission increases by 5.04% and 4.26% at B20+EHN2.5% and B20+EHN5% fuel blends respectively than diesel. The reduction of NO_x emission with the addition of EHN in biodiesel blends is the drop in-cylinder temperature due to the lesser heat release rate.

Moreover, EHN consists of N_2elements in its chemical structure which influences the NO generation.

The higher cetane number increases the rate of increase of distraction of nitrate elements in EHN during the combustion process which results in an improvementin fuel breakdown with reduction of ignition delay [4].

iv. Smoke emission

Figure 9 illustrates the smoke emission variation for various blends of EHN additive with Neem oil methyl ester. The figure describes that both B20 and B20 with EHN additive results inlower smoke emission than conventional fuel. The smoke emission decreases by 7.36%, 15.7% and 20.87% at B20, B20+EHN2.5% and B20+EHN5% fuel blends respectively when compared to diesel fuel. The reason for the reduction of smoke emission using EHN additive in neem oil methyl ester is the advancement of ignition process which allows more time for oxidation of soot particles, due to higher cetane number and therefore smoke emission decreases [4].

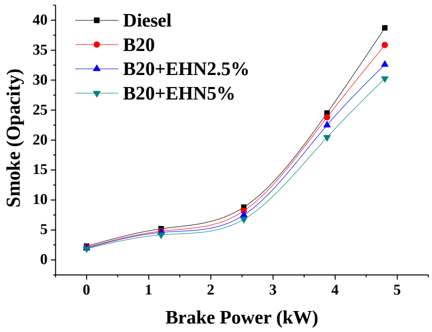


Figure 9 Variation of Smoke emission with Brake power for Neem oil methyl ester with EHN

VI. CONCLUSION

This experimental investigation presents a detailed analysis of EHN additive added neem oil biodiesel blends to evaluate the performance and emission characteristics of a direct injection diesel engine. The BSFC decreased with the addition of EHN additive to the biodiesel blends. The brake thermal efficiency increased with an increase in EHN additive in the biodiesel blends. CO, HC and Smoke emission decreased. The NO_x emission decreased slightly than B20 fuel blend using EHN additive. Overall, the ignition characteristics of a DI diesel engine fuelled by neem oil biodiesel are significantly improved by the addition of EHN additive as cetane improver.

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