Analysis of Performance and Emission Parameters of IC Engine Fuelled with Neem Biodiesel and n-octanol Additives

Pramod Kumar P, Sivanesan Murugesan

Abstract*: The usage of biodiesel as a source in diesel engines is prevalent in recent years in the aim of reducing emission that are produced when using diesel. Researches are undergoing in the fields of alternative fuels to improve the energy content and combustibility of biofuels used in engines. Biodiesel being a renewable energy source is widely used as an alternative for fossil fuel. In this test octanol (Oct) is added to neem biodiesel (NBD) and diesel (D) as an additive to create the fuel blends and its impact upon performance and emission characteristics are evaluated. The fuel properties are found be improved on using higher alcohol additives such as octanol which is having high energy content as well as high cetane number and are also easily miscible in biodiesel and diesel. From the experiment conducted on diesel engine using both diesel as well as with prepared blends, significant decrease for all emission associated with neem biodiesel, diesel and octanol blends was found without any substantial loss of performance compared with results while using neat diesel. The results indicate that blending octanol with biodiesel blends is a viable option as alternative fuel source for CI engines.

Index Terms*: Alcohol additives, Biodiesel, emissions, octanol.

I. INTRODUCTION

The discovery of fossil fuels led the pathway for rapid industrial development all over the world at a new pace. The high demands of fossil fuels by industries and automobiles have gradually depleted the fuel reserves. This has led to price hike and economic crisis along with the consequence of severe pollution produced by burning fossil fuels [1]. Diesel power trains are the commonly used engines for large scale transportation, agriculture and electricity production needs which produces significant amount of exhaust emissions. Diesel exhaust consists of different organic and inorganic compounds as a mixture of particles and gases. These are identified as toxic components that cause severe health risk for living beings [18]. The researches for finding alternative fuel sources to curtail the dependence upon fossil fuels are gaining popularity in the recent decades due to stringent emission norms.

Biodiesel being a renewable and sustainable alternative fuel resource that is distinguished for their ability to replace reliance on fossil fuel. The requirement of minimal modifications to the existing engine for substituting biodiesel with diesel as fuel has led to the popularity of biodiesel among researchers. But the biodiesel is found to have several downsides which includes poor atomisation, high viscosity and increased NOx emissions. Biodiesel production through transesterification can be achieved from any oil yielding feedstocks [16]. The oil obtained from feedstocks are converted into mono alkali esters which have diesel like properties with the help of transesterification process [2]. In this study neem oil is chosen for obtaining biodiesel due to the abundant availability and neem biodiesel is found to have diesel like properties from previous researches. The influence of neem biodiesel and diesel blends upon single cylinder diesel engine was investigated by Jayashri N Nair et al. [3]. From her study it was inferred that using neem biodiesel in diesel at 10% by volume has improved the efficiency with a drop-in emission. The CO, HC and NOx emissions were found to be 3%, 8.5% and 22% lower when compared to diesel. M.S.Gad et al. [4] investigated experimentally the effect of palm oil and palm oil biodiesel blended in diesel as fuel for single cylinder diesel engine on the emission and performance characteristics. He observed reduction in unburned HC and CO emissions while using blends of palm oil biodiesel rather than palm oil/diesel blends. The B20 blend comprising of 20% biodiesel and 80% diesel was found to have desirable characteristics to substitute diesel.

The trend of using alcohols as a fuel source for SI engine to deliver high power and to lower the emissions was present for many years. Commonly used alcohols in SI engines are ethanol or methanol which are short chain alcohols. Infusion of alcohols in CI engines has become an area of interest in recent times. In case of CI engines, alcohols having long chain carbon atoms are preferred as blend components. This is because the higher alcohols are distinguished for their high energy content as well as higher cetane number. The alcohols above butanol are found to form blends of diesel and biodiesel without any phase separations due to their hygroscopic nature and low polarity as a result of carbon content.

D.C. Rakopoulos et al. [5] assessed the effect on emission and performance characteristics using blends of butanol at varying percentage by volume with diesel in a single cylinder diesel engine running at 2000rpm. On comparison with diesel all the emissions were decreased but a surge in unburned HC emission on using butanol blends was

Revised Manuscript Received on June 13, 2019

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observed. From the study conducted by Rajesh kumar et al [6] using octanol as blend component with diesel, he suggested that the usage of octanol had prolonged the ignition delay thereby creating higher cylinder pressure resulting in an increased heat release rate. Adding octanol resulted in the reduction of emission along with increase of performance for naturally aspirated mode. The results of EGR mode showed reduction of NOx and smoke emission but increased CO, HC and BSFC rates. Sundar R et al. [7] conducted an experiment using diesel/hexanol blends with varying hexanol percentage by volume in CI engine. He found a substantial reduction in smoke opacity whereas a surge in NOx emission along with improvement in performance using hexanol/blends over diesel. Jeya Jeevan et al. [8] had investigated the performance and emission characteristics of diesel engine operating with biodiesel/diesel blends, diesel/butanol blends and diesel/pentanol blends as fuel respectively. Deep et al. [9] found reduction in NOx and CO emissions of single cylinder diesel engine when octanol is blended in neat diesel in comparison to diesel. BSFC is found to decline for lower fraction of octanol but increases with increment in octanol proportion.

Nowadays the drawbacks of biodiesel are resolved by using higher alcohols as additives. Octanol is gaining consideration among the researchers not only due to diesel like properties but also due to development of several method of synthesizing using micro-organisms. Zhang et al. [10] doped diesel with octanol up to 30% by volume in a CI engine and found reduction in smoke, CO and NOx on comparison to neat diesel. Arulprakasajothi Mahalingam et al. [11] studied the effect of doping neat mahua biodiesel with varying proportion of octanol on the performance and emission characteristics of a diesel engine. Substantial reduction of all emission parameters was observed at different octanol proportions. B. Ashok et al. [12] investigated the impact on performance and emission parameters on diesel engine fuelled by blends of octanol with calophyllum inophyllum methyl ester (CIME). Upon increasing octanol fraction up to 30%, an improvement in BTE was observed but subsequently reduced upon further increase in octanol fraction. Presence of excess oxygen in octanol helps to lower the CO content and reduce smoke opacity compared to diesel.

Hence the literature review has put forth the feasibility of using octanol as an additive while making blends of biodiesel and diesel to produce alternate fuel source having improved combustion properties and reduced emission characteristics.

1. MATERIALS AND METHODS

EXPERIMENTAL ASSEMBLY

The experiments are carried out on a greaves GL-400 diesel engine. The engine speed is maintained at 2300rpm throughout the experiments. The engine is coupled with 50kW eddy current dynamometer [17]. The engine specifications are denoted in the table 1. The gas analyser used for measuring the CO2, NOx, HC, O_2 is HORIBA MEXA 584L and smoke content is measured using AVL smoke meter 415SE. Exhaust gas temperature is measured with a k-type thermocouple attached to a display unit. The engine is operated using diesel under no load condition and reading are taken. The load is then increased at 25% increment up to full load condition. This process is repeated using different blends and observation are made.

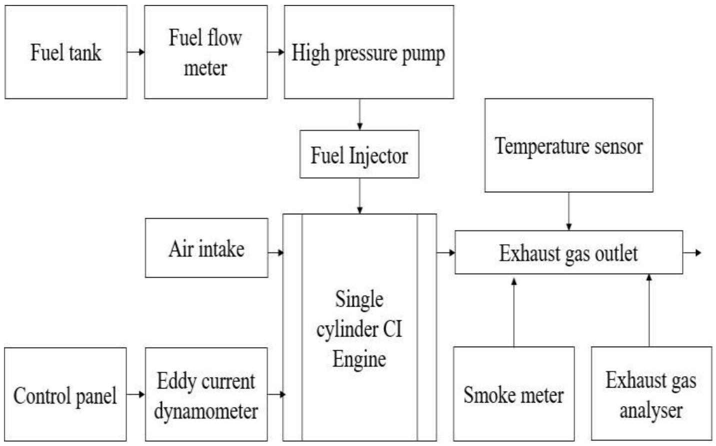
II. BIODIESEL PRODUCTION

Transesterification process is conversion of neem oil into neem oil methyl ester. For maximum yield we use the molar ratio of alcohol to neem oil as 6:1 [13]. Esterification process was done using acid catalyst (H_2SO_4) at 1% by volume of oil and alcohol. Then followed by transesterification using alkali catalyst (KOH) at 1% by weight of mixture. The mixture is heated to 70^0C for 90 min with constant stirring and then left to settle down for 12 hours. The mixture separates into two layers of which the neem oil methyl ester resides on top layer and glycerine at bottom layer. The top layer undergoes series of water washing cycle for removing excess methanol from biodiesel. The water washed mixture is then heated for removing the water content and yields pure neem biodiesel.

III. ALCOHOL

The higher alcohol used for the study is octanol ($C_8H_{17}OH$) which is a straight chain fatty alcohol with eight carbon backbone having properties similar to diesel. Octanol with purity of 98% was used for this experiment.

Fig 2.1: Experiment Layout



TEST FUELS

The blends were prepared by mixing octanol, neem methyl ester and diesel together at varying proportions as denoted in the table 2. For the experiment, three blends of fuel were prepared by mixing octanol (Oct) and neem biodiesel (NBD) with diesel (D) by varying its volume. The blends were checked for solubility and even after several days no phase separation was observed.

Table I: Engine Specifications

Manufacturer	Greaves
Model	GL400
Engine type	Direct injection single cylinder four stroke vertical diesel engine
Bore * Stroke (mm)	86 * 68
Displacement (cm^3)	395
Compression ratio	18:1
Maximum engine output	5.5 kW @ 3600 rpm
Maximum torque (Nm)	20

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Table II: Blend ratios

Blend name	Proportions
D	100%-DIESEL
D80 Oct 10 NBD 10	80%D- 10% Oct-10% NBD
D70 Oct 10 NBD 20	70%D- 10% Oct-20% NBD
D60 Oct 10 NBD 30	60%D- 10% Oct-30% NBD

3 RESULT AND REVIEW

PERFORMANCE ANALYSIS

BRAKE SPECIFIC FUEL CONSUMPTION

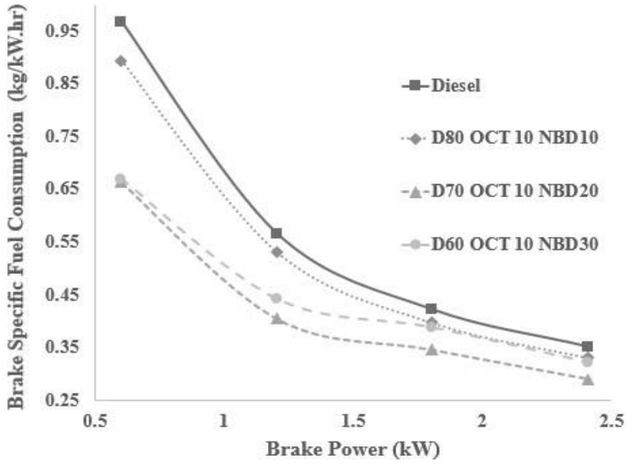

Fig 3.1.1 Variation in BSFC with Brake Power.

The fig.3.1.1 denotes the deviation of Brake Specific Fuel Consumption (BSFC) against Brake Power (BP) at different blends and for diesel at various load conditions. At low load operation, fuel requirement for producing sufficient torque for driving the engine is high. Therefore, at low load operations fuel consumption rate is increased whereas at higher load conditions torque requirement for engine operation is low resulting in reduced fuel consumption. From the graph a significant decline in BSFC is observed for the blends over diesel. This increased performance of the blends despite the lower calorific value compared to diesel can be credited to the effective fuel combustion as a result of elevated O_2 content in both octanol and biodiesel compared to diesel. The blend D70 Oct10 Nbd30 showed lowest BSFC of 31% compared to neat diesel.

BRAKE THERMAL EFFICIENCY

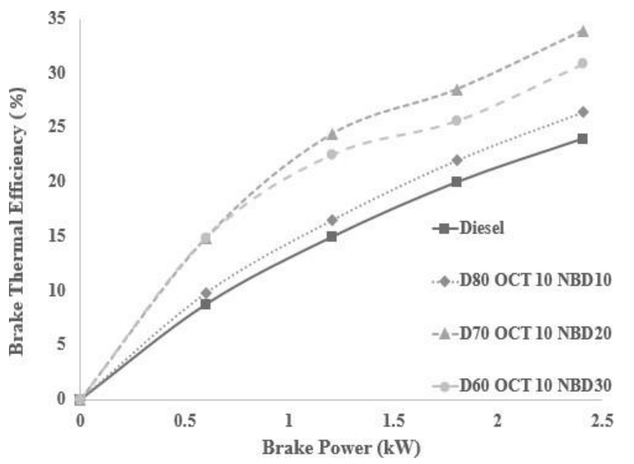

Fig 3.1.2 Variation in BTE with Brake Power.

The fig 3.1.2 portrays the deviation in Brake Thermal Efficiency (BTE) against brake power under varying load conditions while using octanol/blends and neat diesel. When the load is increased, the BTE of the blends also increases with a maximum increase of 43% for D70 Oct10 Nbd30 blend compared to diesel. The conventional diesel combustion relies upon oxygen provided through intake air only whereas the biodiesel/alcohol blends are oxygen rich providing additional oxygen for combustion process. Octanol having low cetane number would result in prolonged premixed phase which leads to effective fuel mixing improving performance and increasing BTE.

EXHAUST GAS TEMPERATURE

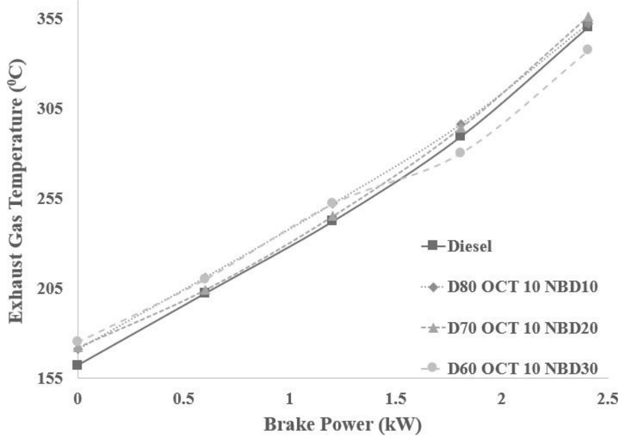

Fig 3.1.3 Variation in EGT with Brake Power.

Fig 3.1.3 shows fluctuation in exhaust gas temperature of blends at varying loads. The exhaust gas temperature is always elevated for blends contrary to diesel. The increase in exhaust gas temperature could be the result of higher oxygen content present in octanol/biodiesel which in turn promotes effective combustion of fuel mixture increasing the temperature of burned gases. The diesel has lower EGT compared to blends because diesel combustion relies upon the O_2 supplied through intake air whereas octanol/biodiesel combustion has infused O_2 content in addition to O_2 present in intake air.

EMISSION ANALYSIS

NITROGEN OXIDE EMISSION

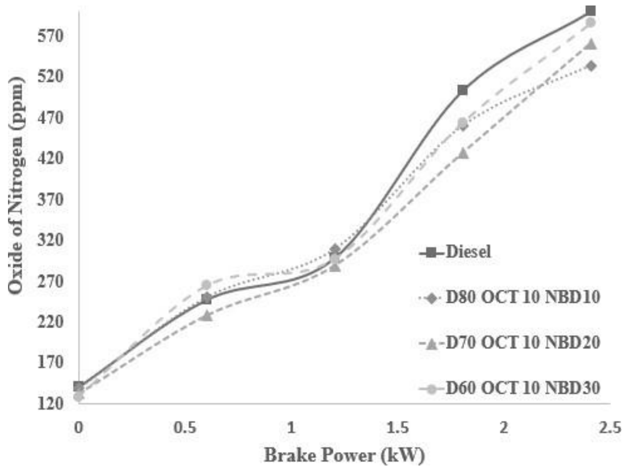

Fig 3.2.1 variation in NO_x with Brake Power

From the fig 3.2.1 the fluctuation in NOx emission for various blend under different load conditions can be inferred. The cause of formation of NOx at low

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temperature is due to the mechanism known as prompt NOx [15]. The formation of NO_x is relative to the cylinder temperature, the O_2 content of fuel mixture as well as time of residence of fuel mixture while combustion process [14]. The NOx emission level is observed to reduce for all blends in comparison to diesel under high load operation. This could be because the latent heat of evaporation is very high for octanol which reduces the in-cylinder temperature thereby retarding formation of oxides of nitrogen. Maximum reduction of 10.9% was observed for blend D80 OCT 10.

UNBURNED HYDROCARBON EMISSION

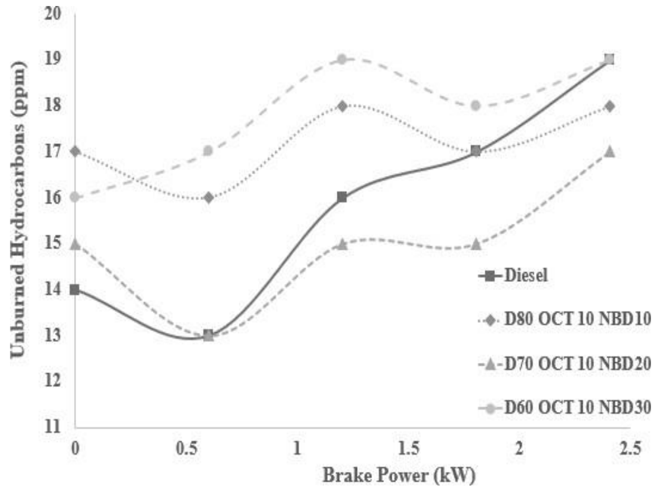

Fig 3.2.2 variation in HC with Brake Power

The variations in HC emission against brake power for various loads are shown in the Fig.3.2.2. when the engine is operated with blends there is an increase in HC emissions for low load conditions in comparison to diesel. This increase of HC can be explained by the flame quenching property of octanol attributed to its high latent heat of evaporation or poor fuel-air mixing or fuel impingement on cylinder walls [10]. The increase of in-cylinder temperature at higher loads decreases the HC emission rate. The maximum decrease of 10.5% was found when D70 Oct10 Nbd30 blend was used in CI engine.

CARBON DIOXIDE EMISSION

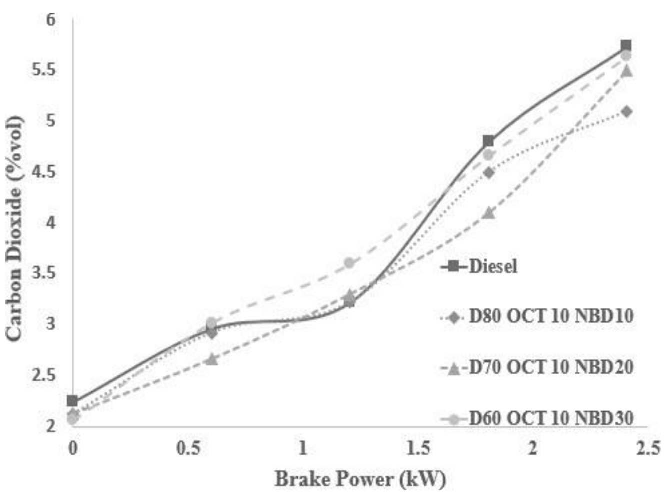

Fig 3.2.3 variation in CO_2 with Brake Power

Deviation in carbon dioxide emission for various loads against brake power are shown in Fig.3.2.3. The D70 Oct10 Nbd30 blend has the lowest CO_2 emission. The presence of CO_2 is related to O_2 content of the fuel. The CO_2 emissions are found to increase along with load.

SMOKE EMISSIONS

Deviation in smoke concentration for various loads against brake power are shown in Fig.3.2.3. the primary reason of smoke is the presence of fuel rich zones inside the cylinder. The increase in smoke concentration under low load operations can be attributed to poor evaporation traits combined with low ignition quality of octanol. This hinders the fuel combustion thereby increasing smoke emission. But at higher load operations, we observe a decline in smoke concentration because of increased in-cylinder temperature along with increased oxygen content provided by the blend for combustion process.

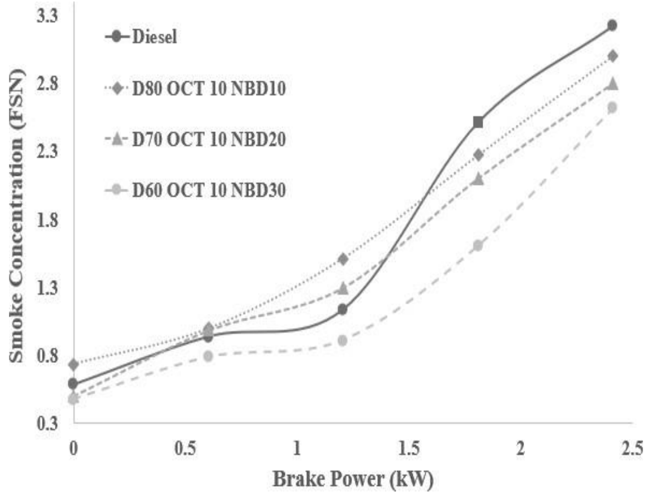

Fig 3.2.4 variation in Smoke concentration with Brake Power

4. CONCLUSION

From the experiment conducted on IC engine fuelled with neem biodiesel and octanol additives, the main conclusion can be outlined as following:

- The neem oil methyl ester, octanol and diesel blends created can be used in CI engine without engine modifications causing any significant losses in performance.
- The blend D70 Oct10 Nbd30 is having highest BSFC of 31% on comparison with diesel.
- There was an increase of 43% of BTE which can be credited to increased oxygen content in the fuel blend D70 Oct10 Nbd30.
- Exhaust temperature is high indicating effective combustion of fuel mixture.
- The latent heat of evaporation is very high for octanol which reduce the in-cylinder temperature thereby retarding formation of oxides of nitrogen. Maximum reduction of 10.9% was observed for blend D80 OCT 10 Nbd10.
- Maximum decrease in HC emission of 10.5% was found when D70 Oct10 Nbd30 blend was used in CI engine.
- At high load operation, smoke

emission reduces due to increase in in-cylinder temperature as well as fuel mixture intake also increases providing more oxygen content.

- D70 Oct10 Nbd20 was found to be the most efficient fuel blend, this could be due to the trade-off between cooling effect of octanol and high oxygen content of neem biodiesel.

Thus, we can conclude that blending octanol with biodiesel blends is a viable option as alternative fuel source for CI engines. This improvement can be attributed to high oxygen content in biodiesel/octanol fuel and also to evaporation property of octanol.

5. FUTURE SCOPE

The above experiment can be conducted by incorporating an exhaust gas recirculation system to the existing setup and the effect of EGR on the blends can be studied.

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