NO_X EMISSION CONTROL TECHNIQUES WHEN CI ENGINE IS FUELLED WITH BLENDS OF MAHUA METHYLE ESTERS AND DIESEL

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ABSTRACT

Producing and using renewable fuels for transportation is one approach for a sustainable energy future worldwide. Renewable fuels also substantially reduce contributions to global climate change. In the transportation sector, ethanol produced from biomass shows promise as a future fuel for spark-ignited engines because of its high octane quality. Ethanol, however, is not a high quality compression ignition fuel. Ethanol can be easily converted through a dehydration process to produce Diethyl Ether (DEE), which is an excellent compression-ignition fuel with higher energy density than ethanol. DEE has long been known as a cold start aid for engines, but little is known about using DEE as a significant component in a blend or as a complete replacement for diesel fuel.This paper attempts to identify the potential of blending DEE with diesel transportation fuel. Engine tests were conducted with 5% 10%, 15% and 20% DEE/Diesel blends. The nitrogen oxide (NO_X) emissions are high and it is necessary to reduce this emission before using methyl ester as a fuel for diesel engines. In the present work, retardation of injection timing and exhaust gas recirculation (EGR) are used to reduce the same. However UBHC, CO and particulate emissions increase when retarding the injection timing. But these pollutants are low compared to normal diesel operation. Injection timing of 20.9^0CA bTDC is found to give optimum results. The adopted concept of exhaust gas recirculation showed considerable reduction in nitrous oxides and slight improvement in bTE for 10% of EGR when the engine is operated at an optimal blend. Further diethyl ether is used as an additive and engine emissions particularly NOx found to be at reasonable level for 10% of DEE addition by not compromising in thermal efficiency and specific fuel consumption.

KEYWORDS: *CI Engine; NOx; DEE; Mahua Methyl Esters*

I. INTRODUCTION

Diethyl Ether (DEE) has long been known as a cold start aid for engines, but little is known about using DEE as a significant component in a blend or as a complete replacement for diesel fuel and engine testing and process information on DEE is limited. Traditionally it has been used as a solvent or extractant for fats, waxes, oils, perfumes, resins, dyes, gums, alkaloids [1]. DEE is estimated to have a high cetane number and is a liquid at room temperature. It looks attractive as a fuel for CI engines due to its low auto ignition temperature, high volatility and wide flammability ranges. Ethanol produced from biomass can be easily converted through a dehydration process into DEE. First evidence of using ethers in IC engine is reported in the period 1919 to 1923 in British Guiana where an alcohol based motor fuel named Alcoline was produced from sugarcane molasses which consisted of approximately 63% ethanol, 35% DEE, and 1% gas oil and pyridine[2]. Near the end of the World War II, blending DEE to ethanol was adopted as an acceptable method to improve performance of ethanol. DEE blending in ethanol for this purpose was limited to 3% by volume due to reduced octane of the DEE/ethanol blends. [3-7]. Gulyamov et. al. [8] in Russia also suggest DEE for use as a starting additive for alcohol based synthetic motor fuels. Antonini [9] reported on DEE as a new option for diesel engine fuels. He suggested e of DEE as an option for diesel engines by mixing it with vegetable oil and/or diesel fuel. Information available on engine testing on DEE is limited. Evaluation of Exhaust NOx and particulate at equivalent operating conditions in a direct-injection compression ignition engine for diesel and diethyl ether fuel reveled that Particulate levels for diethyl ether were very low relative to the diesel fuel and did not increase significantly until the fuel to oxygen equivalence ratio was above 0.8.

The log of fuel specific NOx for both the diesel and diethyl ether fuel were found to correlate well with the inverse of adiabatic flame temperature [10]. In a study of the effect of DEE on the performance and emissions of a four-stroke direct injection diesel engine with different blends of DEE and diesel as fuel, it has been shown that 5% DEE blend gives better performance and low emissions compared to other blends of DEE and diesel fuel [11].

Experiments were conducted on a single cylinder, four stroke, water cooled diesel engine to study the performance and emission characteristics of adding 10 %diethyl ether as an additive with the selected ratio of the emulsified fuel (70D: 30E) Test results indicate increase in brake thermal efficiency and decrease in specific fuel consumption, smoke density, particulate matter and oxides of nitrogen than the diesel fuel no:2 and the emulsified fuel[12]. The heat release investigation, when the engine was run on ethanol and optimum fumigated DEE, has indicated earlier combustion, and very short ignition delay. [13]

As a compression ignition fuel DEE has several favorable Properties like high cetane number and reasonable energy density for onboard storage. Based on a measurement of ignition delay in a combustion bomb cetane number of DEE is reported to be higher than 125 [15].DEE is a liquid at room temperature having boiling point of 34°C, which makes it more attractive in terms of fuel Handling. It can be easily blended with Diesel or any other liquid fuel. However Storage ability of DEE and its blends is a matter of concern due to its tendency of forming peroxides which are explosive in nature. However antioxidant additives may be used to take care of this problem [16]. DEE also has comparatively broader flammability limits .Its lubrication properties are unknown, but these probably pose less of a problem than expected for Dimethyl ether.

In summary, DEE has some attractive fuel properties relative to use in compression-ignition engines, but its properties also raise some concerns. The concerns do not appear to be seriously limiting in nature and may be addressed using appropriate provisions. DEE is also known to be non-carcinogenic, non-mutagenic, and non-toxic. Wallington et al. [17] reported on the reactivity of a series of ethers with respect to hydroxyl radical attack in simulated atmospheric conditions. The reactivity of DEE is predicted to be 5 times higher than MTBE which remains stable for less than four in atmosphere. DEE is estimated to be stable for proximately nineteen hours. However no information about well to wheel green house gases emissions and tailpipe aldehylde emissions from DEE is available.

In the present study combustion, engine performance and emission characteristics of a DI diesel engine fuelled with Different DEE/Diesel blends are investigated. At first Cetane value of different DEE/Diesel blends was estimated on a CFR engine. Based on cetane results it was decided to limit the study to only 5% 10%, 15% and 20% DEE/Diesel blends. Brake power (BP), emissions of nitrogen oxide (NOx), carbon monoxide (CO) and total unburnt hydrocarbon (HC) were investigated and discussed.

When a small percentage of exhaust gas is introduced into the combustion air, the oxygen purity of the combustion air is reduced leading to lower NO_x emissions. This system is widely employed on smaller car and truck engines. Various arrangements have been tested for recirculation, including internal recirculation on 2-stroke engines by timing adjustment, hot and cold exhaust recirculation from the high and low pressure side of exhaust gas -turbocharger. This system is an effective means of NO_x reduction. With a 20% EGR NO_x reduction is in the order of 50% with very little fuel consumption penalty. However, there many engineering challenges to overcome before this system can be a reliable system for marine diesel engines.

II. EXPERIMENTAL SETUP

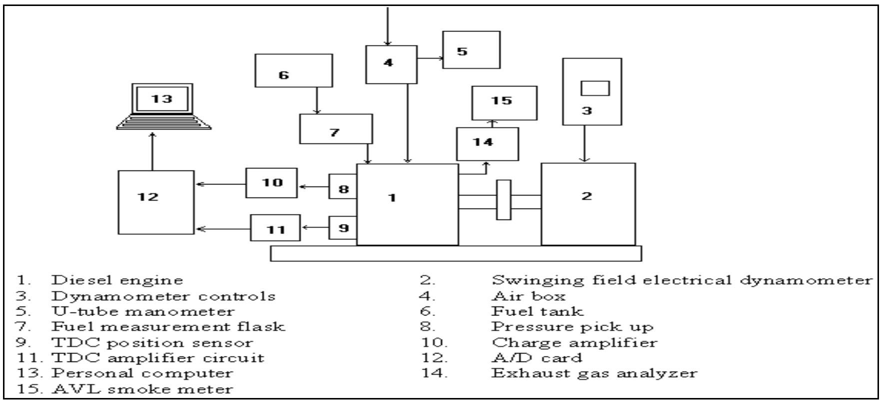

Figure.1: Layout of engine test rig

Table.1 Engine specifications

Engine Type	**Four stroke, stationary, constant speed, direct injection, diesel engine**
Make	Kirloskar
Model	TAF1
Maximum Power	4.4 kW @ 1500 RPM
Maximum Torque	28 N-m @ 1500 RPM
Bore	87.5 mm
Stroke	110 mm
Compression Ratio	17.5:1
Injection Timing	23.4^0 bTDC
Loading Type	Electrical Dynamometer

III. TESTING PROCEDURE

The first step in the testing procedure is to ensure that the valve on by-pass line is completely closed (0% EGR). Then the load is kept at zero and then the engine is cranked. The engine is then allowed to stabilize for some time and then the manometer depression is noted down. This value is taken as 100% atmospheric air or no EGR. At this condition various parameters such as Fuel flow rate, composition of exhaust gas were noted using a 5-gas analyzer. After all the parameters are noted the gate valve on the exhaust line is partially opened to create back pressure. The gate valve in the by-pass line is opened or closed depending on the manometer depression (i.e.) say if we need 10% EGR then the manometer depression is adjusted to 0.9 times of the 0% EGR value and the measurements were taken as before similarly for 20% and 30% re-circulation, the same procedure is followed. Then the load is increased and the same procedure is repeated. The loads used are 0%, 25%, 50%, 75% and 100% of the full load.

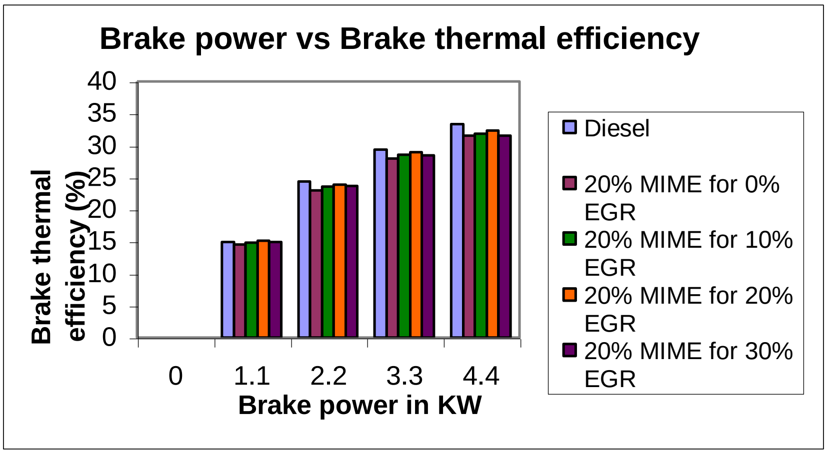

Figure.2 : Variation of Brake thermal efficiency with Brake power for various % of EGR

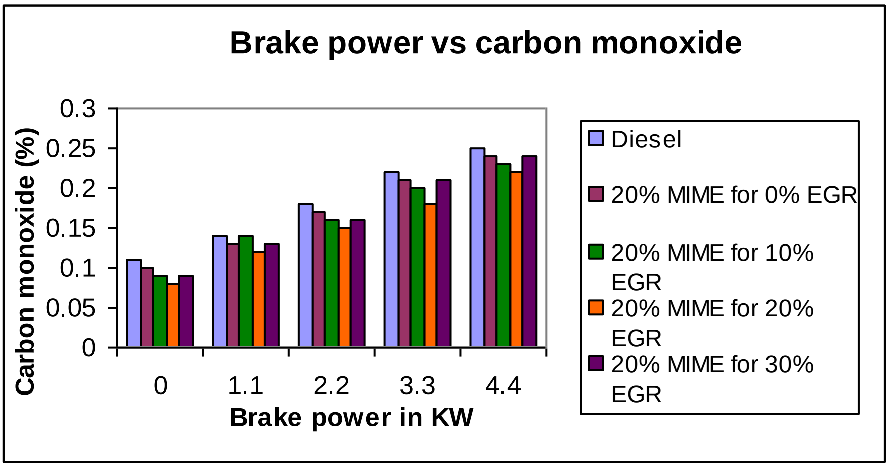

Figure.3 : Variation of Carbon monoxide with Brake power for various % of EGR

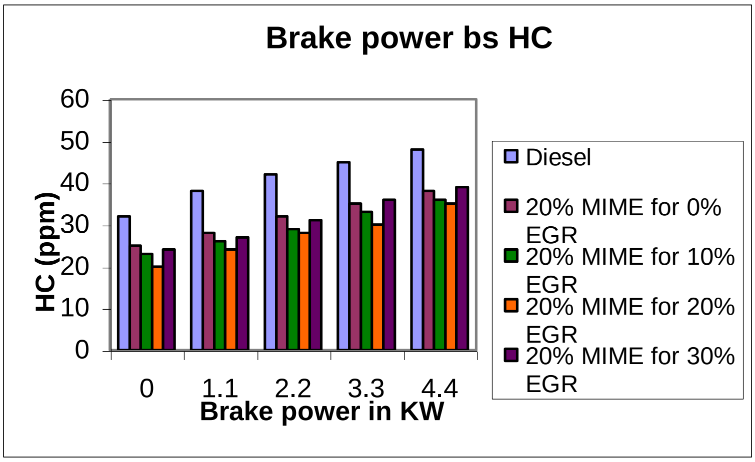

Figure .4: Variation of Hydrocarbon Carbon with Brake power for various % of EGR

The HC emission has decreased from no EGR to 20% EGR and then increased to 30% EGR, as can be seen from Figure.3 and 4 However, HC and CO are minimum at 20% EGR. The CO emission has increased in manifold from no EGR to 30% EGR. This abnormal increase has discouraged further rise in EGR percentage from 30%. The absence of the required amount of oxygen at higher percentages of EGR is the reason for an abnormal increase in CO.

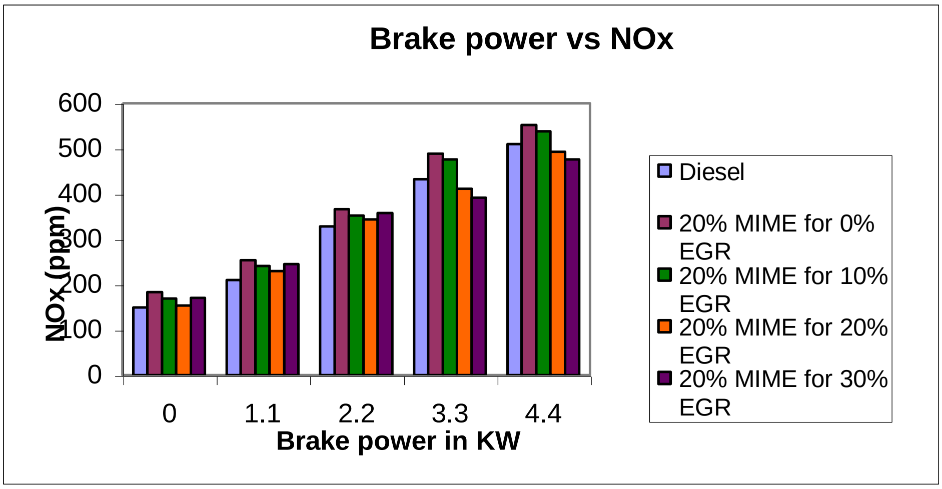

Figure .5: Variation of NOx with Brake power for various % of EGR

At full load NOx decreases from no EGR to 20% EGR as can be observed from Figure.5. The formation of NO in the combustion chamber is due to high pressures and high temperatures during combustion. However, due to circulation of exhaust gas along with the intake air, the amount of intake air was reduced, which, in turn, caused the decrease in the available nitrogen as well as oxygen. However, the inbuilt oxygen in MME compensates the required oxygen for combustion, and the remaining oxygen caused the formation of NO at high pressures and temperatures. Due to this reason, obviously the available oxygen as well as nitrogen are less and lead to the decrease in NO. The other reason for the decrease in NO is the decrease in the peak pressure upon an increase in the EGR percentage.

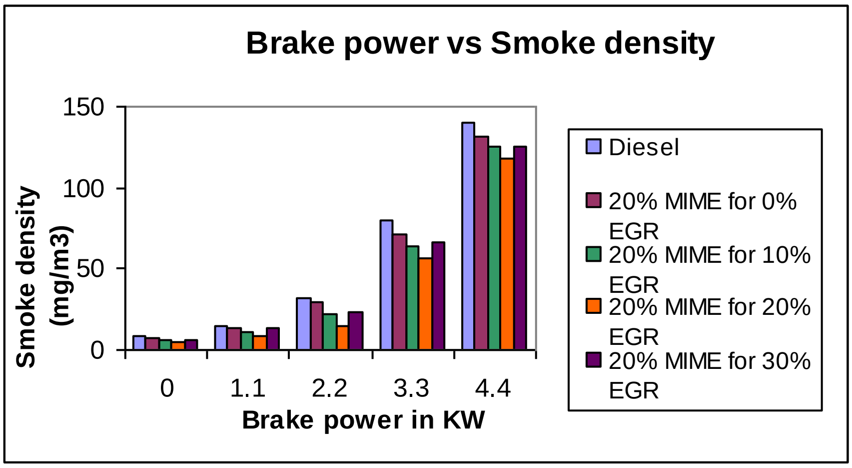

Figure.6 : Variation of Smoke density with Brake power for various % of EGR.

At full load opacity of the smoke has been decreases from no EGR to 20% EGR as can be observed from Figure.6. The opacity of the smoke has been increased to 122 at 30% EGR and minimum has been experienced to 118 at 20% EGR, as shown in Figure.5. So upon increasing EGR, the particulate matter also increases, which is not desirable.

IV. NOx Reduction using Diethyl Ether as an Additive/Blend

Diethyl ether (DEE) can be used as a renewable fuel or fuel additive. DEE has long been known as cold start aid for engines, but little is known about using DEE as a significant component in a blend or as a complete replacement for fuel. It is an excellent engine fuel with higher energy content than ethanol. DEE is liquid at ambient conditions that make it attractive for fuel handling and infrastructure requirements. Storage stability of DEE and its blends are of concern because of its tendency to oxidize and form peroxides in storage. DEE has several favorable properties, including an outstanding cetane number and reasonable energy density for onboard storage. Particularly it possesses higher cetane value. The important properties of diethyl ether are given in Table . 2

Table.2: Properties of diethyl ether

Property	Diethyl ether
Molecular formula	$C_2H_5 - O - C_2H_5$
Cetane number	>125
Stoichiometric air -fuel ratio	11.1
Lower heating value (MJ/kg)	29.25
Specific gravity	0.71

4.1 Engine Tests with Biodiesel - DEE

The engine, which is used in the previous tests, used for the analysis of biodiesel-diethyl ether blends. Diethyl ether is blended with biodiesel in the concentration of 5, 10 and 20%. The performance and emission tests are carried out for load ranging from no load to full load conditions.

V. RESULTS AND DISCUSSIONS

5.1 Brake Thermal Efficiency

The variation of brake thermal efficiency with respect to brake power of various blends tested are presented in Figure. The maximum brake thermal efficiency obtained is about 32.24 % for 5% DEE, which is quite higher than that of 20% MIME (31.52%). DEE has very low self-ignition temperatures and wider flammability limits. DEE initiates the combustion of the air-fuel mixture and hence better and complete combustion takes place. The lower brake thermal efficiency is obtained for higher percentages of DEE in the blend due to the low calorific value.

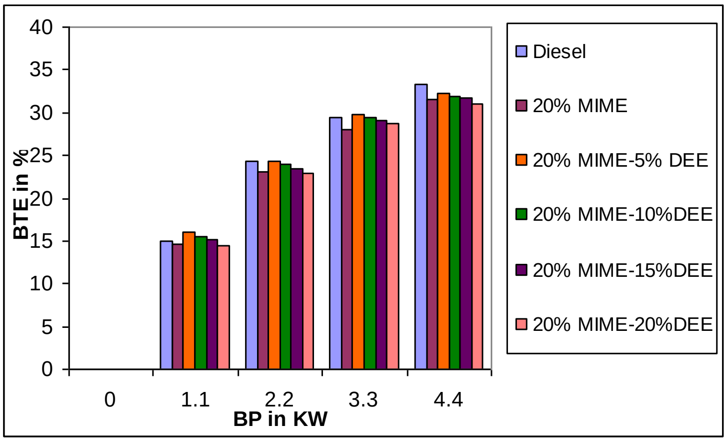

Figure.7: Comparison of brake thermal efficiency of DEE-biodiesel blend fueled engine

5.2 Carbon Monoxide Emission

Figure.8 shows the plots of carbon monoxide emissions of the diethyl ether– biodiesel at the rated engine speed of 1500 RPM at various brake power. CO emission increases with increase in load as expected. This is typical with all internal combustion engines since the air-fuel ratio decreases with increase in load. CO emission is the ideal emission product assessor. CO concentration in the exhaust emission is negligibly small when a homogeneous mixture is burned at stoichiometric air-fuel ratio mixture or on the lean side stoichiometric. With increasing DEE percentage in the blend, CO emission level is decreased for 5% DEE and thereby increases up to 20% DEE due to poor combustion.

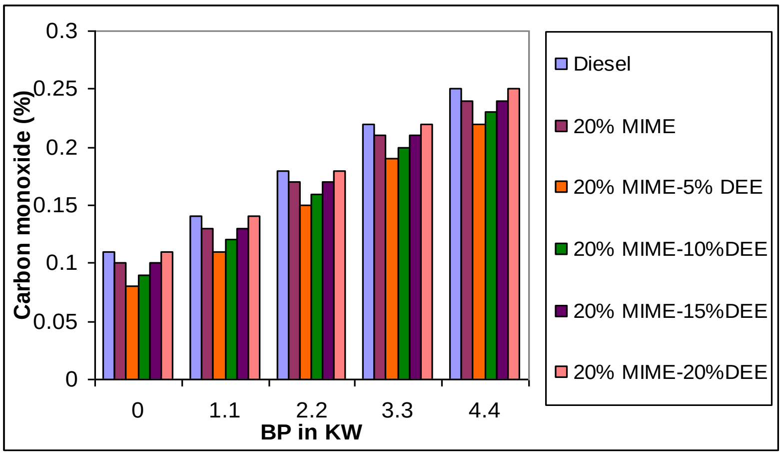

Figure.8: The variation of CO emissions of biodiesel-DEE blend fueled engine 5.3 Smoke Density

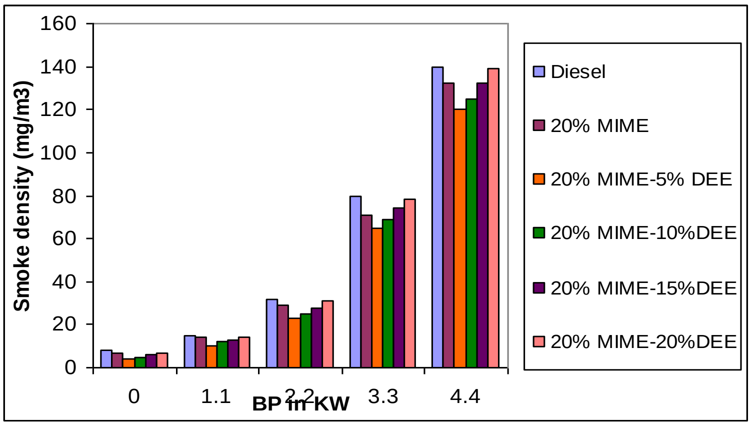

Figure.9: Variation in smoke density of biodiesel-DEE blend fueled engine

Smoke density of 5% DEE–20% DEE is noticed to be generally lower than that of 20% DEE and diesel. That is, lesser amount of unburned hydrocarbon presents in the engine exhaust gas. Thus the lower smoke density values are achieved with biodiesel blends as compared to that of biodiesel.

5.4 NOx Emission

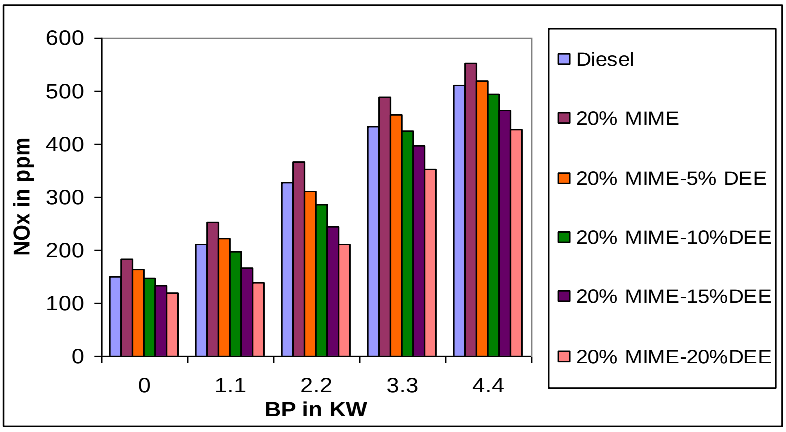

Figure.10: Variation in NOx of biodiesel-DEE blend fueled engine

The NOx concentration varies linearly with the load of the engine. As the load increases, the overall fuel-air ratio increases, resulting in an increase in the average gas temperature in the combustion chamber, and hence NOx formation, which is sensitive to temperature increase. From the figure.10 at all loads the emission NOx for 20% MIME is found to be maximum because all vegetable oils are oxygenated intrinsically. When small quantities of additives like DEE is started adding the NOx content started reducing.

VI. SUMMARY

The recirculation of the exhaust gas into the engine dilutes the gases in the combustion chamber. Hence the temperature inside the combustion chamber reduces, correspondingly NOx emission also reduces. Introduction of EGR in the biodiesel engine reduces the exhaust gas temperature remarkably. The reduction in HC emission and small improvement in brake thermal efficiency are observed at small percentages of EGR into the engine. CO emission increases with EGR because of the reduction in air supply. To improve the performance and emission characteristics of biodiesel fueled engine diethyl ether is chosen as fuel additive. The cetane number of DEE is very much higher as compared to that of diesel/ biodiesel (about 125) and hence used as prospective fuel or performance-improving additive in compression ignition engines. The various blends of biodiesel-DEE are used as fuel in compression ignition engines and its performance emission characteristics are analyzed. The lower percentage concentrations of DEE in the blends are found to be improving the thermal efficiency. The addition of diethyl ether with biodiesel reduces the exhaust emissions well. The present experimental results support that use of DEE as an additive with biodiesel improve the performance and reduce the NOx.

VII. CONCLUSIONS

In summary, the present work reports on the preparation of methyl ester from selected vegetable oil and predicted its combustion, performance and emission characteristics and describes the reduction of NOx techniques when used in diesel engine.

The conclusions have been divided into three subdivisions as follows

1. Effect of injection timing retardation on the performance and emissions
2. Effect of EGR on performance and emissions.
3. Effect of adding Diethyl ether as an additive in small percentages.

Effect of EGR on Performance and Emissions

When the EGR system is used along with the MME, it will cause dilution of the charge as well as a decrease in the intake air so that NO decreases when EGR percentage increased, but engine performance is unstable due to insufficient oxygen, and CO and HC emissions increase to high levels. At full load, MME along with 30% EGR shows lowest NOx but at this percentage, HC and CO are high. Due to this reason, even though NO is less at 30% EGR, it is not preferable. At 20% dilution, the EGR gives low HC and CO as well as improvement in the thermal efficiency close to diesel operation. NOx has also less than the pure petroleum diesel operation at this percentage so that 20% EGR is preferable along with the MME.

Effect of Additive (DEE) on Performance and Emissions

- The addition of diethyl ether with biodiesel reduces the exhaust emissions well. The present experimental results support that use of DEE as an additive with biodiesel improve the performance and reduce the NOx.

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