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AN EXPERIMENTAL INVESTIGATION ON CI-ENGINE USING MADHUCA BLENDS

Girish Kumar.L[S] , Karthik.S.K[S] , Vinay Kumar.P[S] and Vignesh.P[S]
Dr.Raju.B.R[1] , Dr.Surekha.M[2] , Shyamsundar.M[3] and Priyankar Dhole[4]

*[s] – Students of Automobile Engineering Department *[1]- Professor & HOD , Department of Automobile Engineering
*[2]- Professor & HOD , Department of Engineering Chemistry
*[3]- Assistant Professor , Department of Engineering Chemistry
*[4]- Assistant Professor , Department of Automobile Engineering
THE OXFORD COLLEGE OF ENGINEERING
Bangalore, Karnataka
India

ABSTRACT:-

Consumption of fossil fuels has created a demand for the alternative renewable source of energy. In the latter studies it is prominently revealed that the fossil fuel will undergo a depletion in the future lines accompanied with the major drawback was their main participation in polluting the environmental aspects. Therefore, it is necessary to bring out a replacement of the fossil fuel with the significant usage of biodiesel. Henceforth, we have conducted a study on the performance characteristics of a diesel engine using Madhuca Indica oil by transesterification process. The process typically includes the extraction of oil from the seeds followed by the initial purification of the oil. Esterification process was then carried out with the oil and methanol in the molar ratio 1:6 with 2% of acid catalyst (H_2SO_4) and headed with transesterification process with the involvement of oil and methanol in the volumetric ratio 1/3rd along with 4% of heterogeneous catalyst (CaO). The product hence obtained from the above procedure was left for settling and finally the residue was separated and biodiesel was obtained. Different blends of biodiesel were prepared (B10, B20, B30 and B40) and the performance characteristic of diesel engine was carried out with each of the above blends and the readings were obtained. The various engine parameters found were Brake power, specific fuel consumption, thermal efficiency and mechanical efficiency of the engine. The results hence obtained from the different blends were compared with that of the petroleum diesel and a performance graph was successfully plotted. Lastly, the emission test was suitably conducted and the emission percentage of HC, CO, CO_2 and NOx were recorded.

***Key Words :-** Madhuca Indica, Methanol, Catalyst, Transesterification Process, Bio-Diesel Blends, Diesel Engine Parameters.*

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1. INTRODUCTION:-

From the early years of 1890s, introduction of Diesel engines by Rudolf Diesel have made their greater contribution in the field of automobile with the presentation of an effective compression ignition engine but clearly it is also being accompanied with the emission of diesel exhaust which was found to vary depending upon the physical and chemical conditions, the fuel consumption rate and the strength of the composition mixture. However in contrast, lean mixtures give rise to a significant increase in the NOx emission and also a group of organic and inorganic pollutants. For this reason, catalytic convertors came into picture in the recent years which gradually reduced the NOx emission by 90%. But depending upon recent global issues, it was clearly necessary to bring out a complete change in the fuel certainly by the introduction of alternative fuel for the diesel engines which most approximately must possess the fuel properties similar to that of the petroleum diesel. The use of edible oil to produce biodiesel in India is not feasible in view of big gap in demand and supply of such oil. As India is deficient in edible oils, some developmental works have been carried out by government of India for producing bio diesel from non traditional oil.

Madhuca Indica Tree

Madhuca Indica Seeds

Madhuca Indica Oil

Mahua oil is a non-edible oil which is one of the renewable form of energy source. The Madhuca seeds are extensively found and most certainly cultivated in northern part of India and in certain parts of southern India. Annually, 1 lakh to 2 lakh tons of seeds are being produced in India. They grow up to 15m to 20m of height and the fruiting season is usually between June to August during which the seeds are produced and can be stored. Most importantly, the fuel properties of Madhuca oil was found to be within the ASTM standards. Hence it can be significantly used as a biodiesel as an alternative fuel in diesel engines.

Nowadays, there are four known methods to reduce the high viscosity of oils to enable their use in conventional compression ignitions engines: dilution(direct blending with diesel), pyrolysis, micro-emulsion and transesterification. Transesterification however is the current method of choice for study, which results in a fuel similar to diesel. Transesterification is a reaction between a triglyceride and alcohol in the presence of alkali catalyst to produce methyl ester and by-product glycerol. Alkali-catalyzed transesterification is very fast compared to acid catalyzed. However, higher ratio of alcohol to oil is generally used to obtain biodiesel of low viscosity with higher conversion rate. Methanol is widely used in the transesterification and excess methanol is used to cause fast reaction and high degree of conversion.

In this study, Mahua oil methyl ester (MOME) was prepared by using heterogeneous catalyst calcium oxide. The heterogeneous catalyst has a significance in obtaining high yield and conversion of triglycerides to biodiesel. And also in heterogeneous type, the catalyst can be separated easily and reuse up to 8-9 times. Trans-esterification conversion is complicated if oil contains higher amounts of FFA (>1%) and also there will be a chances of soap formation with alkaline catalyst. The soap can prevent separation of the biodiesel from the glycerol fraction. Crude mahua oil contains about 18% FFA, which is far beyond the 1% level. The reduction of FFA <1% is best if esterification followed by Transesterification. Although the ester is the major product, desired recovery of glycerol is important because of its industrial uses.

The problem with processing these low cost oils and fats is that they often contain large amounts of free fatty acids that cannot be converted to biodiesel using alkaline catalyst. Therefore, two-step Esterification process is required for these feedstocks. Initially the FFA of these can be converted to fatty acid methyl esters by an acid catalyzed pretreatment and in the second step transesterification is completed by using alkaline catalyst to complete the reaction. If the oil has high free fatty acid content and more water, acid catalyzed transesterification is suitable. Reaction time is the controlling factor in determining the yield of methyl esters.

2. EXPERIMENTAL PROCEDURE CONDUCTED :-

2.1 EXTRACTION OF OIL FROM THE SEEDS :-

The seeds from madhuca indica were collected in such a way that ,the seeds maintain upto 50% of moisture in kernels. The oil from the seeds are extracted by either crushing method or solvent method. Then the seed kernels are passed through the mechanical expellers, where high pressure is used to squeeze the seeds to get crude oil from the source. And further the same is initially purified by using 25 micron filter paper to get refined oil, which is used for the synthesis of biodiesel. The left over seeds after the extraction can be preserved in the form of cakes and can be used for further extraction.

2.2 ACID VALUE TEST:-

Initially, the free fatty acid value of the filtered oil was found by volumetric analysis (Generally FFA lies between by 15% to 20% for fresh oil). A titration begins with a conical flask containing extracted Madhuca Oil and Isopropyl alcohol in the ratio 1:10 . 2 to 3 drops of phenolphthalein was added to conical flask as an indicator. A standard 0.1N NaOH solution was prepared by dissolving 4g of NaOH pellets in 1liter of distilled water and this solution taken into the burette. The titration was carried out until the colour of the solution in the conical flask turn from light yellow to pale pink(usually for oils , change in colour disappears in 30 to 40 sec has been noted as end point of titration) . Once the end point is reached, the process is stopped and the volume of NaOH consumed is noted down and FFA value was found.

$$AH^{+} + BOH^{-} + Hph \longrightarrow AB + H_2O + H + ph$$

The formula used to find FFA content :-

$$\text{ACID VALUE (\%)} = \frac{V \times N \times A}{} \times 100$$

W

Where ,

- V - Volume of NaOH consumed in ml (burette reading).
- N - Normality of NaOH solution.
- A - 28.2 (Molecular weight of oleic acid divide by 10).
- W- Weight of oil sample in grams.

2.3 PROPERTIES OF OIL AND DIESEL :-

Various test methods were carried out on both the petroleum diesel and the Madhuca Indica oil before the beginning of the actual biodiesel synthesis process are listed below :-

- Acid value or free fatty acid concentration test.
- Flash point and Fire point.
- Cloud point and Pour point.
- Density test.
- Viscosity test.

The characteristic properties hence obtained from the above test methods are clearly displayed in Table 1

PROPERTIES	PETROLUEM DIESEL	MADHUCA OIL
DENSITY(kg/m^3)	800	932
FLASH POINT (^{0}C)	70	220
FIRE POINT (^{0}C)	75	245
CLOUD POINT (^{0}C)	-10 to -15	13
POUR POINT (^{0}C)	-30 to -15	15
FREE FATTY ACIDS (%)	NA	16.88
VISCOSITY RATING(mm^2/s)	2.4	25

2.4 EXPERIMENTAL SETUP:-

The experimental setup for the process comprises of hot plate provided with an automatic magnetic stirrer. A three necked RB flask of 1000ml capacity is used for the experiment which rests over the hot plate. A reflux condenser attached to the larger neck of the RB flask, which is used to recover the methanol being evaporated during the process. One of the smaller necks is provided with a thermometer to measure the temperature of the reaction inside the flask and other neck is tightly sealed with a cork. At intermittent intervals, the cork is opened to pipette out the sample. The complete representation of the setup is shown.

2.5 ESTERIFICATION:-

A known amount of Madhuca Indica oil (500ml) and methanol in molar ratio 1:6 was taken into the 1 lit capacity three neck RB flask and 2% of conc.H_2SO_4 as a catalyst was carefully added to the reaction. The whole setup was placed on a hot plate with magnetic stirrer and temperature of about 60 ^{0}C to 65 ^{0}C was constantly maintained throughout the reaction process. A reflux condenser provided with circulating cooling water was also employed to recover the evaporating methanol back to the reaction mixture. At every 15 minutes interval, a 1ml of reaction sample was pipette out from the flask and titration process was carried out and reduction in the FFA content was observed. Finally the Esterification process was carried out until the FFA value was complimentarily less than 1% and the reaction was stopped. The reaction process consumed nearly 1.5 hours. The product was then cooled first and poured into a separator and left it to settle for one day. At the end, two layers were observed. The bottom layer was residue along with the catalyst and the top layer contained the acid esters with the reduced FFA value.

The chemical reaction involves:-

$$\text{Triglycerides+ methanol (or ethanol)} \xrightarrow{\text{Acid Catalyst}} \text{acid esters+ water}$$

2.6 TRANSESTERIFICATION:-

The 500 ml of acid ester from the Esterification process was again taken into the three necked RB flask and known volume of methanol was added as per the volumetric ratio 3:1. The 4% of heterogeneous catalyst CaO was also added to mixture and similarly the setup was placed on hot plate and a reflux condenser was used. The standard reaction time maintained was about 4 hours. The temperature was kept constant to about 60^{o}C to 65^{o}C since the boiling point of methanol was found to be 62.5^{0}C. The chemical reaction involved in this process is :-

$$\text{Acid esters+ methanol (or ethanol)} \xrightarrow{\text{Base Catalyst}} \text{methyl esters+ glycerol}$$

The yield of biodiesel can be calculated from the following formula:-

$$\text{YIELD OF BIODIESEL (\%)} = \frac{\text{METHYL ESTERS PRODUCED (g or ml)}}{\text{AMOUNT OF OIL TAKEN (g or ml)}} \times 100$$

2.7 SEPERATION AND PURIFICATION PROCESS:-

After the reaction time was completed, the products was cooled and then poured into the separator and was left it for 24 hours. At the end, three layers were significantly formed. The catalyst having the highest density had settled at bottom, the glycerol having the medium density acted as the layer floating above the catalyst and the methyl esters having the lowest density compared to all was found to be floating at the top. Three layers were separately collected into a beaker. The catalyst was dehydrated back into powder form and was reused again for the next process. Finally, the methyl esters were obtained which is nothing but the biodiesel.

Initially, biodiesel from the transesterification process was taken into a beaker. A weighed amount of EDTA crystals (about 10g) were taken in a separate beaker. Slowly the EDTA was added into the beaker containing the biodiesel and left it settle for about 2 days. After settling process, it was observed that the EDTA settled at the bottom hence by trapping the presence of catalyst and any other impurities. Finally the biodiesel was separated from the beaker which was found to be the purest form of biodiesel.

3. TEST CONDUCTED ON METHYL ESTERS:-

The same initial test methods conducted on the Madhuca Indica oil was conducted on the methyl esters obtained from the transesterification process and certain satisfactory values were established. The values thus obtained were compared with the ASTM standards and were found to be within its limits as shown in table 2.

Table.2:- PROPERTIES OF BIODIESEL AS PER THE ASTM STANDARDS

PROPERTIES	METHYL-ESTERS (BIODIESEL)	ASTM STANDARDS
DENSITY (kg/m^3)	823	800-875
FLASH POINT (^{O}C)	208	>130
FIRE POINT (^{O}C)	215	>65
CLOUD POINT (^{O}C)	6	Depends on season
POUR POINT (^{O}C)	1	-------
FREE FATTY ACID (%)	0.8	<1
VISCOSITY (mm^2/s)	4.0	2 to 6

4. ADVANTAGES OF BIODIESEL OVER PETROLEUM DIESEL:-

- Biodiesel can be used as an alternative fuels in any existing Diesel engines without having any negative impact on its operating performance.
- Petroleum diesel and biodiesel can be interchangeably used and as well as blended.
- Since the properties of the biodiesel successfully meets with that of the petroleum diesel, it can easily used on diesel engines without making any significant changes in the operating conditions of the engine.
- Use of biodiesel significantly reduces the emission of unburnt hydrocarbon, particulate matter and also carbon monoxide from the exhaust.
- Most importantly, biodiesel extends the life of the engine because of its better lubricating properties with reduced wear and tear losses.

5. PERFORMANCE TEST ON ENGINE:-

Various blends of Madhuca oil methyl esters were prepared such as B10, B20, B30 and B40. An attempt was made to run the above blends in a diesel engine maintaining a constant speed of about 1500rpm. The various important engine parameters found were the brake power, indicated power, mechanical efficiency and thermal efficiency.

Single Cylinder, Four Stroke Diesel Engine

5.1 ENGINE SPECIFICATION:-

ENGINE TYPE – VARSHA 2
SINGLE CYLINDER, FOUR STROKE
DIESEL ENGINE
COOLING SYSTEM – AIR COOLED
LOADING SYSTEM – D.C GENERATOR WITH RHEOSTAT

The emissions of HC, NOx, CO and CO2 from the diesel exhaust were also recorded and satisfactory reduction in the pollutants were gradually observed and compared with that of the petroleum diesel. The graphs were hence plotted for the different blends of biodiesel.

6. RESULTS AND DISCUSSION :-

6.1 ENGINE PARAMETERES:-

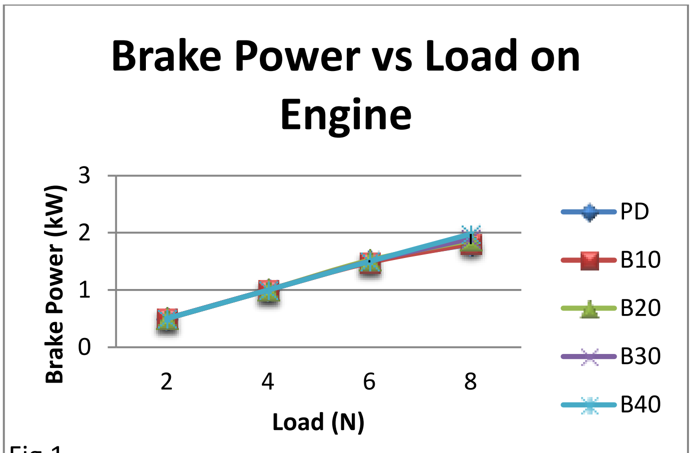


Fig.1

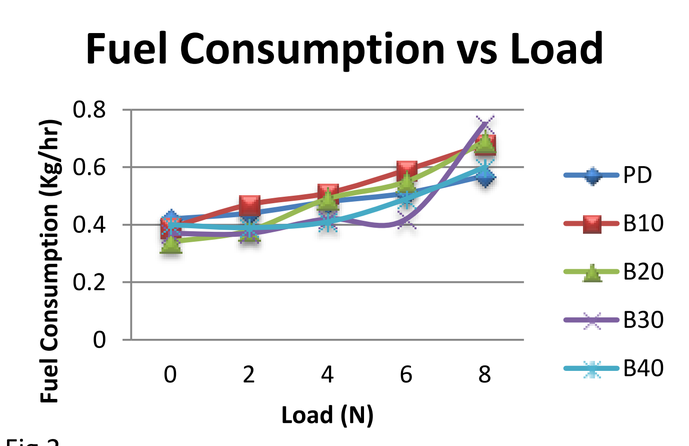


Fig.2

6.1.1 Effect on brake power of the engine

Fig.1. shows the performance characteristics of brake power with respect to load for different blends of biodiesel. The graph displays that with increment values of load simultaneously the brake power is increasing. The break power for Mahua biodiesel is slightly higher than the diesel for all loading conditions. It is observed that at a particular load of 8N the brake power with respect to the blend B40 is found to be greater than the normal petroleum diesel.

6.1.2 Effect on fuel combustion of the engine

Fig.1. shows the performance characteristics of fuel consumption with respect to load for different blends of biodiesel. At a particular load with the various blends it will illustrate that the fuel consumption varies as per the load acting. Thus it can be concluded that the consumption of fuel basically depends upon the % of blend as well as the load acting on engine.

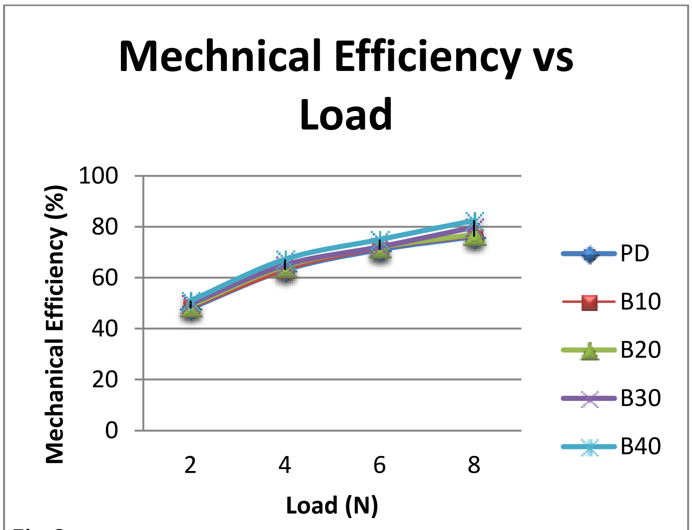


Fig.3

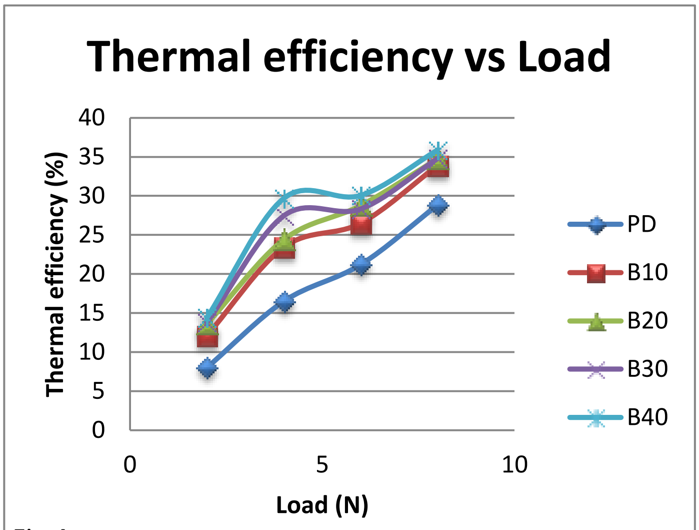


Fig.4

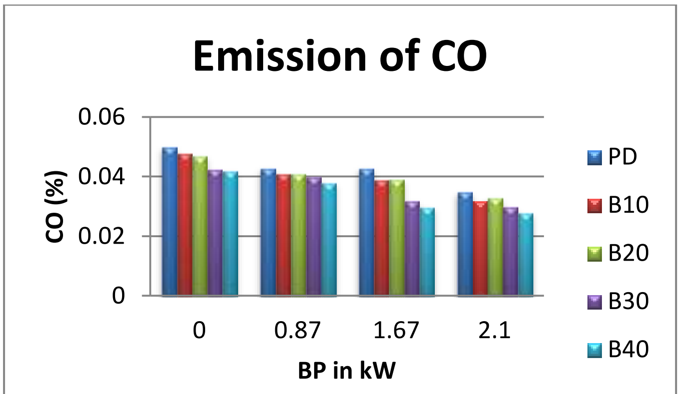
6.1.2 Effect on mechanical efficiency of the engine

The loading on mechanical efficiency is shown Fig.3. From the entire test carried out, the mechanical efficiency was found to be approximately the same for all the blends and diesel. A significant increase in the mechanical efficiency was observed with B40 blend for every different loads acting on the engine.

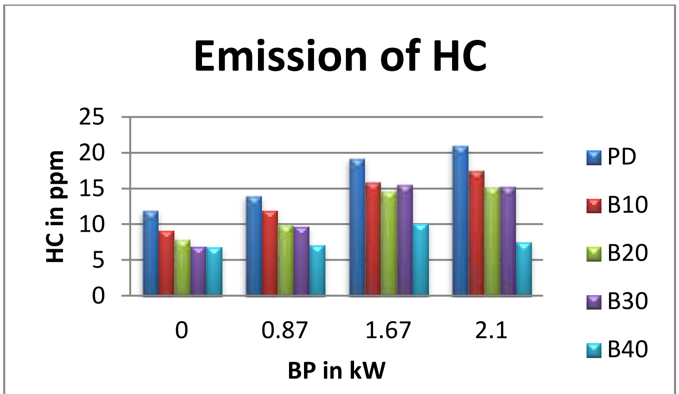
6.1.3 Effect on break thermal efficiency of the engine

The effect of thermal efficiency with respect of the load is as illustrated in the Fig.4. When compared to the petroleum diesel, the blends of biodiesel shows characteristic increase in the thermal efficiency as the load acting on the engine increases and is found to be maximum in case of B40 blend.

6.2 EMISSION PERFORMANCE CHARECTERISTICS:-



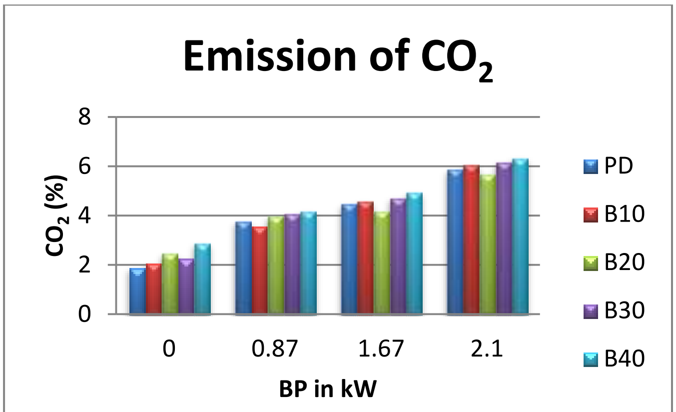
Graph 1



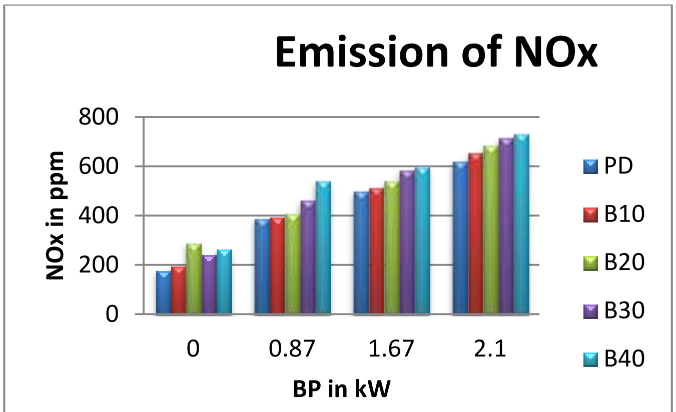
Graph 2

The emission of CO is usually found to be high in % in case of pure petroleum diesel. From the above characteristic features along with the variations of the biodiesel blends shown in Graph 1, it was clearly observed that there was a significant decrease in the CO emission as the proportion of biodiesel blend was gradually increased. Since CO is toxic in nature and of variable behavior, biodiesel can hence be replaced to reduce the emission to a certain extent.

Graph2 shows the effect of BP on HC emission when diesel engine has run on B10, B20, B30, B40 and Petroleum diesel. It shows that HC emission increases with increasing BP and decreases with increase in percentage of ester. B40 has minimum HC emission at all loads. B10 has maximum HC emission than all blends but lower than pure diesel.



Graph 3



Graph 4

The Graph 3 shows the variation of CO2 emission with respect to the BP. The carbon dioxide gradually increases with increasing the BP for all blends. The CO2 emission is very low with B10 when compared to other blends. By using higher content Mahua biodiesel blends it increases the CO2 emission was noted because of incomplete combustion in the engine.

In Graph 4 the effect of BP on NOx emission when diesel engine has run on B10, B20, B30, B40 and Petroleum diesel is shown. The NOx emission increases with increase in the percentage of Biodiesel. B10 and B20 have minimum NOx emission at no load. The primary reason of higher NOx emission of Mahua oil biodiesel fuel is contributed towards inbuilt oxygen. B10, B20 fuel shows lower NOx emission compared to B40. With increase in Mahua methyl ester percentage in blend the oxygen content increase and hence higher blend shows higher NOx emission compared to diesel.

7. CONCLUSION:-

From the comparative study, various blends of methyl esters were prepared from Madhuca Indica oil as a main source gave a significant variation in the performance characteristics was observed as well as a productive reduction in the emission exhaust was accounted from the conventional diesel engine. The blend of Biodiesel with B40 was furnished to give the optimum results when compared to that of other blends and the petroleum diesel with the reduction of CO and HC. It was also noted that the blend B30 has gives better reduction in fuel consumption. From the above test it can be concluded that the biodiesel produced using Madhuca oil can be successfully used as a blend with petroleum diesel and further reduction in cost was importantly noted. Since a heterogeneous catalyst CaO was used, it was particularly reused back for the next following process. A final yield of 86% of Mahua methyl esters was approximately estimated.

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