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Experimental Study on Diesel Engine using Hevea Brasiliensis Biodiesel Blend with Di Tertiary Butyl Peroxide Additive as fuel

A. A. Muhammad Irfan
PG Scholar
Department of Mechanical Engineering
Government College of Technology
Coimbatore-641013

Dr.S.Periyasamy
Assistant Professor
Department of Mechanical Engineering
Government College of Technology
Coimbatore-641013

***Abstract*— Nowadays Biodiesel is a fuel produced from various plants, animal fats, and waste cooking oil. It is emerging a promising alternate energy source for CI engine instead of diesel. The biodiesel is renewable, non toxic and eco friendly in comparison with the fossil fuels. In this project work, biodiesel made from non edible oil source Hevea Brasiliensis was studied. The transesterified Hevea Brasiliensis oil blended with diesel at 10%, 15%, 20% (volume) was prepared and the performance of engine, emission characteristics were analyzed in single cylinder 4-stroke diesel engine. The ignition improver Di Tertiary Butyl Peroxide (DTBP) was added by 1% (volume) with the biodiesel and the experiment was conducted as earlier. It was observed that there was decrease in average brake specific fuel consumption (BSFC) was 5.92% and the increase in brake thermal efficiency was 6.72% with the additive added biodiesel in all three samples compared to the non additive biodiesel. The average reduction in NOx, HC and CO emission were also noticed as 16.06%, 9.46% and 16.27% respectively in the additive added biodiesel. From the experimental investigation it was proved that the Hevea Brasiliensis can be a potential source for biodiesel production and can also be used as fuel for diesel engine with no engine modifications.**

Keywords*— Hevea Brasiliensis, transesterified, ignition improver, Di Tertiary Butyl Peroxide, brake specific fuel consumption, brake thermal efficiency, emission characteristics.

I. INTRODUCTION

The gradual depletion in world petroleum reserves and those impacts on environmental pollution arises the need for suitable alternative fuels to use in diesel engines. In view of this, biodiesel is used as a potential alternate fuel for internal combustion engine. The researchers had turned towards the biodiesel with a scope to reduce emissions in diesel engines. The biodiesel produced from various plants were compared with diesel fuel by researchers in order to have better alternative biodiesel.

Forson et al. [1] investigated the increase in fuel consumption due to lower calorific value and higher specific gravity of biodiesel. The CV of Jatropha biodiesel was about 7% lower compare to diesel. Forgiel et al. [2] had studied the increase in NOx emission using Jatropha biodiesel compared to pure diesel. The reason may be due to late burning (high ignition delay) of blends. Morshed et al. [3] had studied Hevea brasiliensis (natural rubber) is a perennial farm crop belonging to the Euphorbiaceous ancestors, originating from South America and usually cultivated in tropical and subtropical climate regions.

Zhu et al.[4] investigated Hevea brasiliensis oil has high free fatty acid content and it desires to go through a distillation process to trim down its acid value and eliminate some fatty materials, thereby enhancing the quality of the oil for extended storage. Ahmad et al. [5] reported that the high free fatty acid content of Hevea brasiliensis oil has been condensed through a two-step acid esterification base transesterification process. This process is necessary to get better fuel properties that increase the quality of biodiesel**.**

Serrano et al. [6] had studied different parameters such as the methanol to oil molar ratio, catalyst concentration; reaction temperature, reaction time, and speed agitation were performed to obtain the highest methyl ester yield of biodiesel production since these non-edible oils.

Ramadhas et al. [7] evaluated the engine performance and emissions of a diesel engine fueled by methyl esters of rubber seed oil. Their outcome showed that the lesser concentrations of biodiesel blends found to develop the thermal efficiency.B10 biodiesel blend gives a superior enhancement in the brake thermal efficiency of diesel engine by about 3% at the rated load setting. Same development has been drawn to emission, smoked density, and brake specific fuel consumption when using B10. Still, with increase in biodiesel blends NOx emission is also projected to increases NOx emission formation is a highly temperature dependent phenomenon and the exhaust gas temperature increased as a role of concentration of biodiesel in the blend. The experimental outcome proved that the use of biodiesel (created from untreated rubber seed oil) in compression ignition engines is a viable alternative to diesel.

K.Senthil kumar and R.Thundil karuppa raj [8] noticed that the BSFC increases with increase in percentage of ethanol in the blend and satisfactory improvement is achieved by adding the cetane enhancer DTBP for bio ethanol blends. K. Venkateswarlu et al. [9] Observed that the addition of DTBP influences in significant NOx reduction and ignition delay on fish oil diesel blend. Purushothaman et al. [10] studied the addition of DTBP causes a slight reduction in bsfc and increase in brake thermal efficiency on Pongamia biodiesel.

II. MATERIALS AND METHODS

A. *Experimental setup*

The experimental setup as shown in Fig. 1 is the single cylinder four stroke direct injection diesel engine with eddy current dynamometer loading and water as coolant.

Fig.1. Photograph of experimental setup

The engine is used for the evaluation of performance parameters and emission characteristics of pure diesel and HBME biodiesel blends with Di tertiary butyl peroxide. The blend percentages 10, 15 and 20 (% volume) of HBME biodiesel were taken for the estimation of performance and emission characteristics. The engine specification in which the performance parameters were evaluated was given in the below Table I.

B. *Preparation of biodiesel*

A two stage process is used for the transesterification of Hevea brasiliensis oil. The first stage is acid esterification. This process is to reduce the free fatty acids content in Hevea brasiliensis oil by esterification with methanol and acid catalyst sulfuric acid in one hour time at 57^{0}C in a closed reactor vessel. The Hevea brasiliensis oil is first heated to 50^{0}C then 0.7% of weight of sulfuric acid is to be added to oil and methyl alcohol about 2:1 volume ratio is added. Methyl alcohol is added in excess amount to speed up the reaction. This response was scheduled with stirring at 650 rpm and temperature was controlled at 55-57^{0}C for 90 minutes. After dewatering the esterified oil is fed to the transesterification process.

500 ml of esterified Hevea brasiliensis oil was measured and poured into a 2000 ml three necked round bottom flask. This oil was heated up to 60^{0}C. In 250 ml beaker a solution of potassium oxide was prepared using 0.5 wt. % sodium hydroxide pellets with 10:1 volume ratio of oil to methanol. The solution was properly stirred until the potassium hydroxide pellet was completely dissolved. The solution was then heated up to 60^{0}C and slowly poured into preheated oil. The mixture was stirred vigorously for one and half hour. The mixture was allowed to settle for 24 hours in a separating funnel. Later, upper deposit biodiesel was decanted into a separate beaker while the lower layer which comprised glycerol and soap was collected from the bottom of separating funnel. The Hevea brasiliensis methyl ester was washed with distilled water to remove the entrained impurities and glycerin. In this process, 50% (v/v) of distilled water at 60 ^{0}C was sprayed over the esters and shaken gently. This process was repeated several times until the methyl ester becomes neutral.

TABLE I. ENGINE SPECIFICATION

Manufacturer	Kirloskar oil Engine Ltd., India
Type of Engine	Direct Injection Diesel Engine
Number of Cylinders	Single Cylinder
Number of strokes	Four Stroke
Cooling type	Water Cooling
Engine Speed	1500 rpm
Brake Power	3.5 kW @ 1500 rpm
Bore Diameter	80 mm
Stroke Length	110 mm
Type of Loading	Eddy Current Dynamometer
Method of Starting	Manual Cranking
Compression Ratio	16.5 : 1
Orifice Diameter	0.02 m
Dynamometer Arm Length	0.185 m

C. *Properties of Hevea brasiliensis methyl ester*

The fuel properties like density, flash point, fire point, and kinematic viscosity were determined as per the ASTM standards. The properties of pure diesel and Hevea brasiliensis methyl ester used for blending with diesel and for the calculation of engine performance parameters is given in the table II.

TABLE II. PROPERTIES OF FUEL

Property parameters	Unit	Diesel	HBME
Density	g/cc	0.834	0.887
Flash point	^{0}C	69	166
Fire point	^{0}C	62	182.5
Kinematic viscosity	cSt	3.23	5.88

III. RESULT AND DISCUSSION

A. *Performance characteristics*

The performance test was conducted in a DI diesel engine fuelled with various biodiesel blends with and without the di tertiary butyl peroxide additive. The engine was running at constant speed of 1500rpm for all load conditions and the time taken for 10cc fuel consumption was noted to calculate the performance parameters.

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*1) Brake Specific Fuel Consumption:*The brake specific fuel consumption for the additive added and non additive added Hevea brasiliensis biodiesel was compared with the brake specific fuel consumption of base fuel diesel at different blends. The variations in specific fuel consumption with the different loads are shown in Fig. 2.

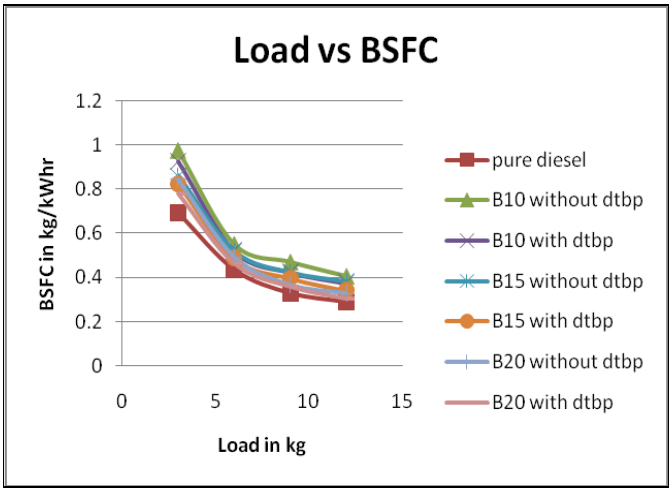

Fig.2. Brake Specific Fuel Consumption

It was observed that the specific fuel consumption of DTBP additive added biodiesel blend of 20% was closely approximated to the pure diesel for all load conditions.

2) Brake Thermal Efficiency: The brake thermal efficiency for the additive added and non additive added Hevea brasiliensis biodiesel was compared with the brake thermal efficiency of base fuel diesel for different biodiesel blends. The variations in brake thermal efficiency with the different loads are shown in Fig. 3. It was observed that the brake thermal efficiency of DTBP additive added biodiesel blend of 20% was closely approximated to the pure diesel for all load conditions.

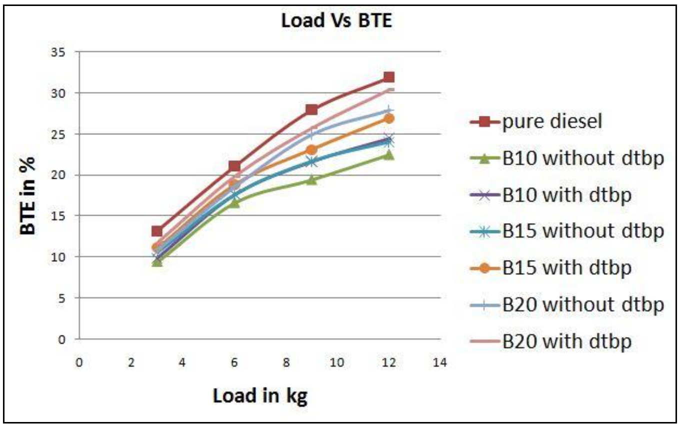

Fig.3. Brake Thermal Efficiency

B. Emission characteristics

The exhaust gas emission test at different loading condition for the various blends were examined with the aid of I3SYS gas analyzer. The smoke meter has the capacity to measure the exhaust gas emissions namely HC, NOx, CO and CO_2.

1) HC Emission: The formation of HC emission during combustion process under various loads for different biodiesel blends was shown in Fig.4.

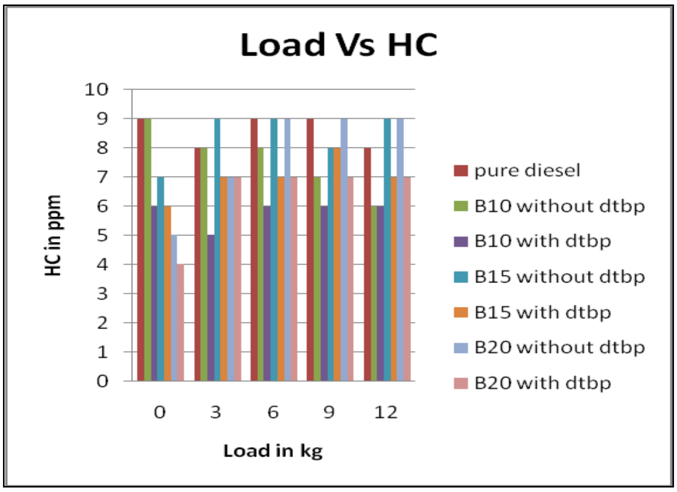

Fig.4. Hydrocarbon Emissions

Biodiesel blends shows reduced HC emission due to the combined effect of its high oxygen content and higher cetane number. Due to fuel borne oxygen enhances the oxidation of unburned HC, thus reducing HC significantly. Addition of DTBP with all blends decreases the unburned HC emission compared to non additive blends as well as HC emission of pure diesel.

2) Oxides of Nitrogen: Oxides of Nitrogen is highly depends on the temperature and pressure inside the engine cylinder. The formation of NOx emission during combustion process under various loads for different biodiesel blends and pure diesel were shown in Fig.5.

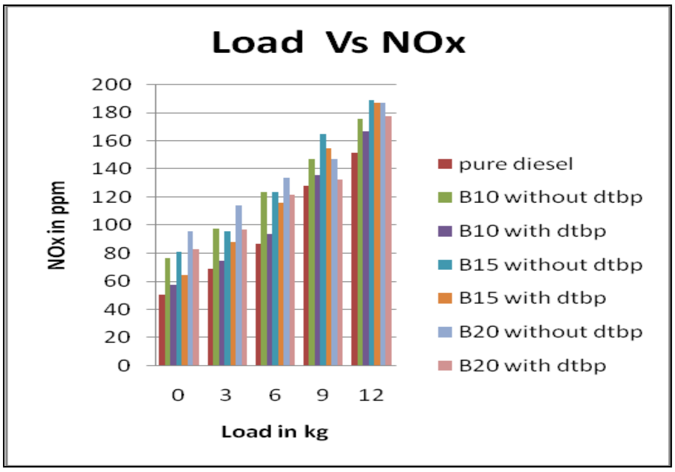

Fig.5. Oxides of Nitrogen Emission

The NOx emission of biodiesel increased compare to the pure diesel for all load conditions. The addition of DTBP additive with the Hevea brasiliensis biodiesel shows significant reduction in NOx emission compare to the non additive biodiesel for all loads. However, the NOx emission was higher in both cases compare to pure diesel. .

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*3) CO Emission:*The formation of CO emission during combustion process under various loads for different biodiesel blends and pure diesel were shown in Fig.6. Biodiesel blends shows reduced CO emission due to combined effects of high oxygen content and high cetane number. The addition of DTBP additive with the Hevea brasiliensis biodiesel shows significant reduction in CO emission compare to the non additive biodiesel and pure diesel for all load conditions.

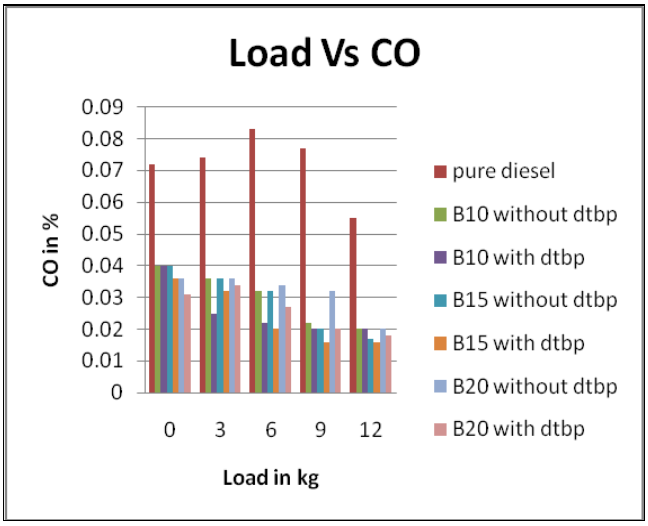

Fig.6. CO Emission

4) CO_2 Emission: An increase in CO_2 emissions for biodiesel blends is observed from Fig.7. CO_2 emissions pose a intimidation to the atmosphere as it a major constituent for the source of global warming. But as products of combustion it is more acceptable compared to CO which is a result of incomplete combustion. The addition of DTBP additive shows the increase in CO_2 emission compare to the non additive biodiesel and pure diesel.

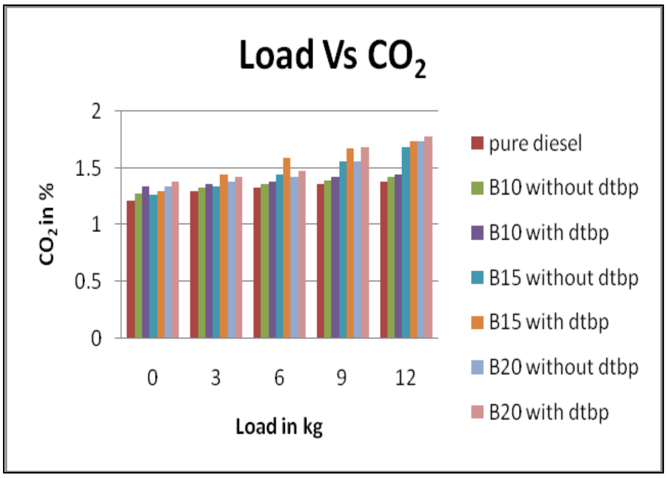

Fig.7. CO_2 Emission

IV. CONCLUSION

The following conclusions were made from the study,

- The biodiesel made from Hevea brasiliensis oil shows the potential to be a feedstock for biodiesel production. The performance, emission characteristics were analyzed at 10%, 15% and 20% blend with and without the presence of DI Tertiary Butyl Peroxide (DTBP) additive in single cylinder 4 stroke direct injection diesel engine.
- An average decrease in brake specific fuel consumption (BSFC) of 5.92% was found in the DTBP added Hevea brasiliensis biodiesel compare to non additive biodiesel. The additive added biodiesel at 20% blend shows the BSFC was approximately closer to BSFC of pure diesel.
- An average increase in brake thermal efficiency (BTE) of 6.72% was found in the DTBP added Hevea brasiliensis biodiesel compare to non additive based biodiesel. The additive added biodiesel at 20% blend shows the BTE was approximately closer to BTE of pure diesel.
- The use of DTBP added Hevea brasiliensis biodiesel shows an effective reduction of 9.46% in HC emissions and 16.27% in CO emissions compare to the non additive based biodiesel.
- As a result of improved combustion, reduced peak pressure and peak temperature inside the engine cylinder in additive added biodiesel shows the effective reduction of 16.06% in NOx emissions compare to the non additive based biodiesel. However, NOx emission is higher than the pure diesel in both the biodiesel blends.
- The Hevea brasiliensis can be a potential source for biodiesel production and can also be used as fuel for diesel engine with no engine modifications.

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