International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-11, September 2019

The Experimental Features of a Compression Ignition Engine Running on Pure Diesel and Mixtures of Diesel and Manilkara Zapota Methyl Ester

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***Abstract**: presently, the world is grieving with lack of energy sources, since the petroleum reserve are being depleted very soon, moreover the world's temperature is rapidly increasing resulting from the emissions of automobile. More consideration should be given to this issue so, the researchers across the globe making difficult trials to find the best substitute energy reserve which swaps the fossil diesel petroleum. This article deals with manilkara zapota methyl ester, the biodiesel taken from a non-edible feed stock Manilkara Zapota seed generally known as Sapodilla. It has exceptional fuel properties like fossil diesel. By the transesterification process, Manilkara Zapota Methyl Ester (MZME) was taken out from crude manilkara zapota seed oil. Numerous test samples were equipped in the combination ratios ranging from 10% to 30% and the mixtures were selected as ZB10D90 (10% MZME + 90% Pure Diesel), ZB20D80 (20% MZME + 80% Pure Diesel) and ZB30D70 (30% MZME + 70% Pure Diesel). An experimental examination was performed on a single cylinder four stroke direct injection diesel engine to find out the emission, combustion properties, and performance at continuous speed and numerous load circumstances. The experimental outcomes were exposed that, at complete load condition, the performance aspects like BSFC and BTE were improved by 7.69% and 7.44% respectively, and the parameters of emission like CO was reduced greatly by 64% whereas NO_x, HC and smoke opacity were concurrently increased by 12.36%, 6.67%, and 3.88% respectively, but no big variance was found in the emission of CO_2 when compared to diesel fuel. Heat release rate was decreased by 5.04% and cylinder peak pressure was improved slightly.*

***Keywords**: Fuel Properties, Manilkara Zapota Seed, Manilkara Zapota methyl ester, Sapodilla, Transesterification*

I. INTRODUCTION

The persistence for fossil fuel is growing as the rise in the population of vehicle. The total vehicle population containing non-transport and transport in 2015 was 210 million, according to the source from Ministry of Road Transport and Highways. It includes 13.6% jeeps, cars and taxis, 73.5% two wheelers, 4.4% things truck, 1% buses, and 7.5% additional vehicles. In India, the vehicle populace formation has displayed important difference during the time 1951-2015 [1]. But inappropriately, the development in vehicles and petroleum reserves availability have become inversely proportional to each other, and also there is bigger ecological uncompromising rules on air pollution, had produced wide spread interest in scholars to express and test the bio-fuels fit for these days. As of now, several vegetable seeds including non-edible and edible such as Jatropha, Neem, Karanja, Cotton seed, Pongamia, Rapeseed, and Soybean etc. were found positive in the biodiesel production.

The earlier work of numerous academics [2-20] has described that, the biodiesel blend with predictable diesel has significantly decrease the deplete emissions and rises the performance of engine. The biodiesels obtained till now are not sufficient to encounter the worldwide requirement of fuel therefore exploring other possible sources as an auxiliary for conservative fuels is a requirement.

Ashish Dewangan et al. and R. Satish Kumar et al. have presented a third-era biodiesel supply called Manilkara Zapota Seed Oil. From Manilkara Zapota Seed, they have formed crude Manilkara Zapota oil (MZO) using a mechanical expeller and stated that Manilkara Zapota seeds has got an oil extract of 23-30% [2,3,4]. Manilkara Zapota id generally known as the sapodilla. It can raise with an average trunk diameter of 1.5 m to more than 30 m tall. In India, it is commonly called chiku, cultured for fruits are liked all over the nation. The fruit is a plump berry capricious in size, shape and weight (75-150g), protected by a coarse brownish skin including 1 to 12 seeds of black or brown colour. It is made into juice and jam or eaten raw. Th sap made by the fruit flesh with milk is one of the world's famous healthy drinks in foods. The seeds are not used for any main persistence except seeding [3,4,5]. The current research was performed on a one-cylinder direct dose Kirloskar made diesel engine powered with M. Zapota biodiesel and fossil diesel mixtures in the proportions ranging from 10% to 30%. From M. Zapota crude oil, the biodiesel was prepared through the process of transesterification. M. Zapota methyl ester's physicochemical properties were measured and equated with those of clean diesel. The investigation was performed at varying load conditions from zero to full load and constant speed (1500 rpm) with pure diesel, and trial samples ZB10D90, ZB20D80, and ZB30D70. The parameters of combustion (maximum rate for heat release, cylinder pressure for peak,

Manuscript published on 30 September 2019.
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exhaust gas temperature), engine performance (BTE, BSFC) and parameters of emission (CO, HC, NOx and Smoke opacity) were discussed for evaluation.

II. MATERIALS AND METHODS

A. Biodiesel Preparation

The essential amount of Manilkara Zapota seeds were composed and were desiccated under the straight sun light for about 24 hours for eliminating 10% content from moisture [3]. The dried seeds shells were manually removed. After the removal of the shells, the seeds were crumpled by a power-driven screw sort of expeller to excerpt oil. The estimated content of oil in Manilkara Zapota seed stays between 23% and 30% of the seed's weight [2,3]. After the oil extraction, it was sifted and heated at 60^0C for water content removal present in it. Lastly, it was exposed to the process of transesterification for the conversion of crude Manilkara Zapota seed oil into Manilkara Zapota methyl ester.
Transesterification is an organic procedure of altering bid branched triglyceride molecules of plant fats and oils into minor molecules of straight chain, just like the size of diesel fuel molecules. This method takes place due to the reaction between alcohol (Methanol-CH_3OH) and vegetable oil under the impact of the catalyst (NaOH or KOH) [2-20].

In a round bottom flask, 1000 ml of crude M. Zapota oil is taken. 250 ml of methanol and 12 grams of potassium hydroxide alkaline catalyst is evaluated and is taken in a beaker. Potassium hydroxide is mixed with the methanol and it is mixed till KOH is completely dissolved in methanol. The crude M. Zapota oil was taken in a round bottom flask and with the help of magnetic stirrer, it is heated and stirred simultaneously at 110 rpm. When the crude oil's temperature reaches 60^0C approximately, the alcohol and catalyst mixture solution is transferred into the flask with crude seed oil and the bottle is closed with a lid. Now at high speeds of 720 rpm, the mixture is heated with continuous stirring. Here consideration should be given for the solution's temperature not to exceed 60^0C as the methanol get vanished at the temperature more than 60^0C. To stop the evaporation of methanol during the reaction, a condenser for water-cooling was used for vapour condensation and send it back to the reactor. The Oil-KOH-Alcohol solution is transferred to a separating funnel after two hours and then without stirring let it to cool overnight. After the cooling is completed, two layers were seen. The top layer was M. zapota methyl ester and bottom layer was glycerol. Then for repeated water wash, the biodiesel is subjected until no glycerin is in the biodiesel. At last, the biodiesel is heated to 100^0C to vapourize the water particles linked with it. The outcoming product is the Manilkara Zapota biodiesel, which it is used in the engines of compression ignition. Manilkara Zapota methyl ester's thermophysical properties are displayed in table 1.

Table 1. Thermo-physical Properties of M. zapota seed Biodiesel

Property of Fuel	Diesel ASTM(D975)	Biodiesel ASTM(D6751)	MZME
Density (Kg / m^3)	820 - 860	860 - 900	878
Kinematic Viscosity @ 40^0C (mm^2 / S)	2.6 – 5.7	1.9 – 6.0	4.52
Flash Point (^{0}C)	60 - 80	Min.130	170
Cetane Number	40 - 55	Min.47	47
Calorific Value (Kj / Kg)	42000-46000	---	39415

B. Experimental setup

The experiment was performed to determine Manilkara Zapota methyl ester blend's (ZB10, ZB20 and ZB30) on emission, performance and combustion features of a diesel engine and elated to that of pure diesel fuel. The schematic representation and photographic view of a diesel engine test rig is shown in the figures 1 and 2. Kirloskar TV 1 single cylinder four stroke water cooled straight injection diesel engine 5.12 KW brake power at 1500 rpm of persistence speed was used for carrying out the experiment. The engine specifications are shown in table 2.

Fig.1 Photographic view of experimental Test Rig

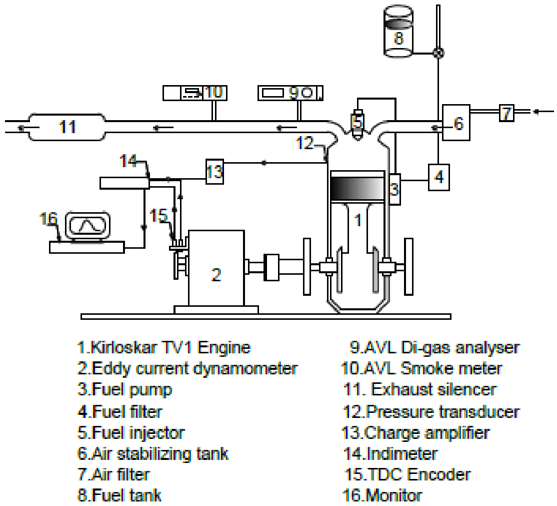

Fig.2 Schematic Layout of Experimental Test Rig

The engine was equipped with eddy current dynamometer, thermocouples, crank angle sensor to read the temperature of air, exhaust gas and water. AVL 444 five gas analyzer was used to quantity the exhaust emissions and the smoke density was measured by AVL smoke meter.
The gas analyzer's specifications eddy current dynamometer and smoke meter were shown in tables 3, 4 and 5 respectively. The combustion parameters were measured with help of TDC encoder, pressure sensor and data acquisition chord with the computer's help.

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Table 2. Specifications of the Test Rig

Make	**Kirloskar**
Model	TV 1
Type	Single cylinder, four stroke, vertical diesel engine
Rated Power	5.12 KW
Rated Speed	1500 rpm
Cylinder bore	87.5 mm
Stroke	110 mm
Compression ratio	17.5 : 1
Cooling	Water cooling
Loading	Eddy current dynamometer

Table 3. Specifications of the Eddy current dynamometer

Make	Techno Mech
Model	TMEC - 10
Max.KW	7.5
Speed (rpm)	1500 – 6000
Dynamometer arm length	185 mm

Table 4. Specifications of AVL DI Gas 444 N (Five Gas Analyzer)

Measurement Data	**Resolution**
CO - 0. – 15% Vol	0.0001 % Vol
HC – 0 – 20000 ppm Vol	1 ppm / 10 ppm
CO_2 – 0 – 20% Vol	0.1% Vol
O_2 – 0 – 25% Vol	0.01% Vol
NO_X – 0 – 6000 ppm Vol	1 ppm Vol

Table 5. Specifications of AVL 437C Smoke Meter

Measurement Data	**Resolution**
Opacity – 0 – 100%	0.1%
Absorption (K Value)	0– 99 – 99 m^{-1}0.01 m^{-1}

C. Experimental Procedure

Primarily, at rated speed, the test engine was run for few minutes for stabilizing purposes. Then the engine could run with diesel at numerous loads in the series of no weight to full weight with 25% augmentation. At very load, emissions like NOx (Nitrogen Oxides), HC (Hydro Carbon), CO_2 (Carbon dioxide), Co (Carbon monoxide), the fuel consumption and EGT (Exhaust gas temperature) were noted. The same process was repetitive for the test fuel mixtures (ZB10D90, ZB20D80 and ZB30D70). So, the investigational results were discussed and analyzed.

III. RESULTS AND DISCUSSIONS

A. Characteristics of Performance

The changes in brake specific fuel consumption (BSFC) with regard to brake power for diesel and numerous mixtures of biodiesel and diesel is displayed in figure 3. BSFC represents the efficiency for altering fuel’s chemical energy into some useful work. In general, BSFC reduces with rise in load and brake power. This is due to the circumstance that at advanced loads burning can improve as the in-cylinder temperature is high because of low energy losses. It was noticed at full load condition that ZB20D80’s BSFC is 240g/KW-hr and it was brought down by 7.69% compared to conventional diesel.

The difference of brake thermal efficiency (BTE) with regard to brake power for test fuel and diesel fuel mixtures is displayed in figure 4. The BTE was improved with rise in brake power for all the fuel blends. This was due to the heat loss reduction with rise in power. At full load condition, it was observed that among all the biodiesel and diesel blends, ZB20D80 formed maximum BTE with regard to biodiesel and it was enhanced by 9.44% as the efficacious burning took place with oxygen-rich biodiesel.

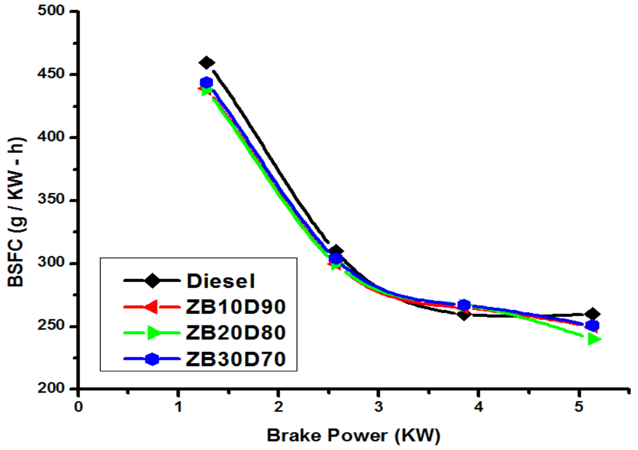

Fig. 3 Variation of BSFC with B.P

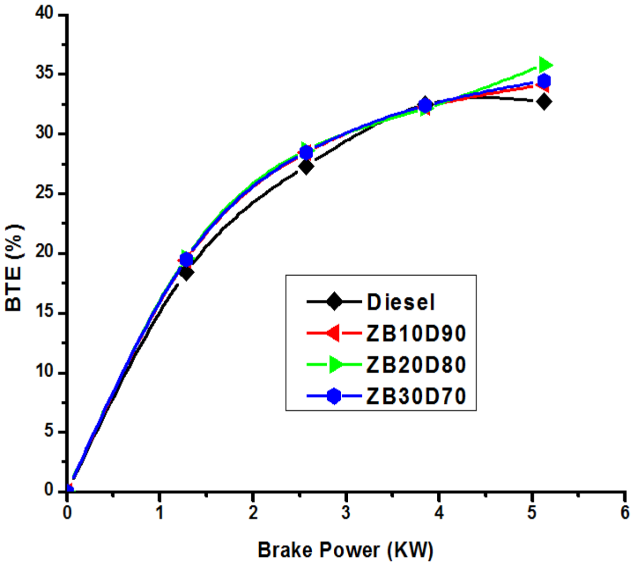

Fig. 4 Variation of BTE with B.P

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B. Characteristics of Emission

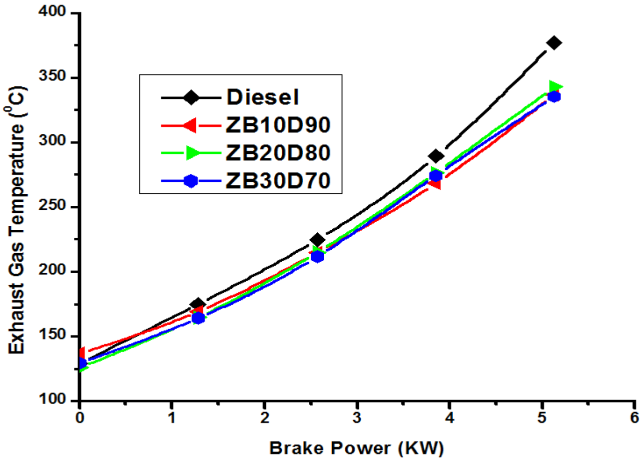

Fig. 5 Variation of E.G.T with B.P

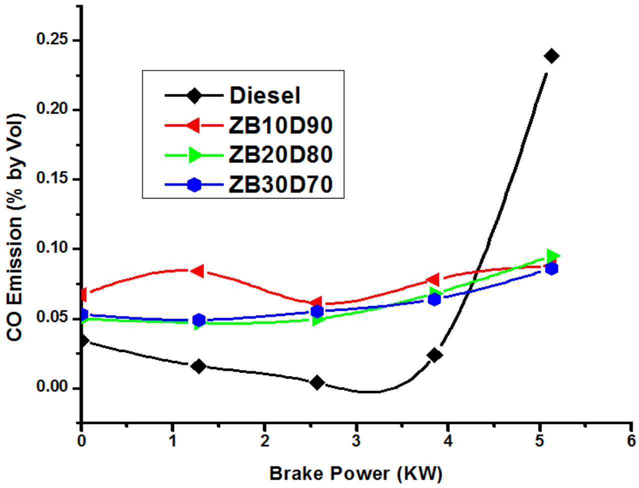

Fig. 6 Variation of CO with B.P

The variation of exhaust gas temperature (EGT) with brake power is shown in figure 5. The EGT improved with brake power increase. It was confirmed that for biodiesel blends the increase in the EGT is gentler when compared to pure diesel. this is because of the maximum use of heat energy in the power conversion. It was determined that the EGT of ZB30D70 is 335.33^{0}C at full load condition and decreased by 11.11% when compared to fossil diesel.

The difference of CO release matching to brake power is displayed in figure 6. It discloses that the CO percentage increases with brake power increase, but the increase rate of biodiesel blends is pretty slow when compared to diesel. it was disclosed that at full load state, the CO percentage of ZB30D70 is 0.086 and it was reduced greatly by 64% when compared to conservative diesel.

The variation of emission of CO_2 with brake power for biodiesel and diesel blends is displayed in figure 7. It was observed that for all the loads the percentage of CO_2 is almost same for the pure diesel and biodiesel mixtures.

The difference of HC emission with regard to brake power for test fuels and diesel is displayed in figure 8. It was noticed that HC increases as the brake power increases. But the variance in HC production for ZB30D70 and diesel is roughly equal at each load. There is a slight increase in the HC percentage of ZB30D70 by 6.67% when related to diesel at whole load condition.

The change of NOx emission about various blends of biodiesel and brake power for diesel is displayed in figure 9. It was recognized from the figure that the quantity of NOx improved with a rise in brake power for all the verified fuels, as with rise in brake power, the temperature inside combustion chamber increases, resulting in improved NOx. This is because of the NOx formation, which is a phenomenon dependent on temperature; the image shows that the emission of NOx of all the biodiesel mixtures is more than diesel. At full load, among all the blends, ZB30D70 is increased by 12.36% compared to diesel and displays less amount of NOx.

The dissimilarity of smoke opacity connecting to brake power for all the verified fuels are depicted in figure 10. The percentage of smoke opacity existing in the exhaust gas measures the particulate matter present in the exhaust gas. From the image, it is observed that the smoke opacity of all the mixtures is more than that of pure diesel, this was because of the poor instability and inappropriate mixing of fuel droplets and air because of biodiesel blend's higher viscosity. Off all the blends at full load ZB30D70 is slightly increased by 3.88% compared to fossil diesel and has recorded less percentage of smoke opacity.

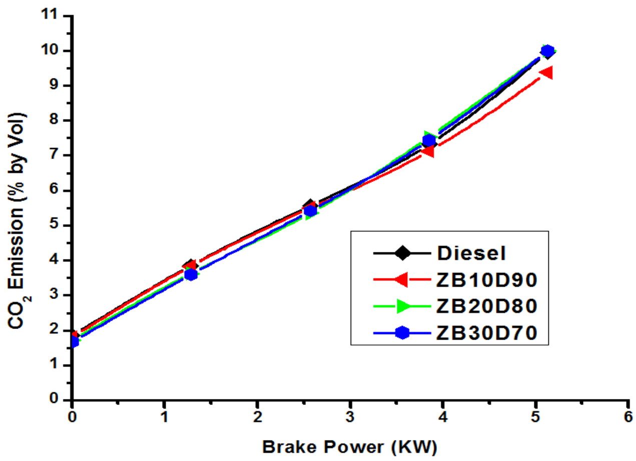

Fig. 7 Variation of CO_2 with B.P

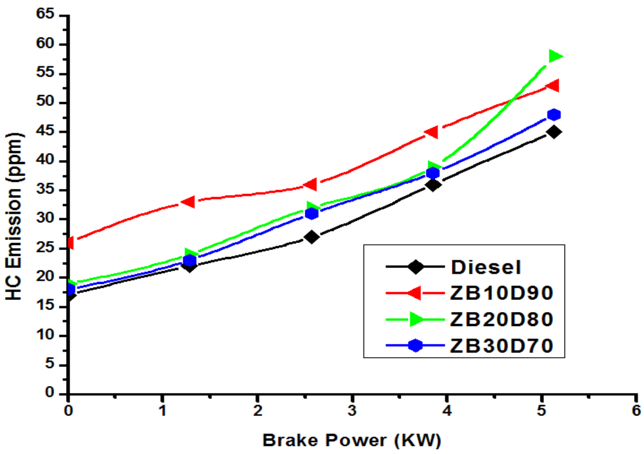

Fig. 8 Variation of HC with B.P

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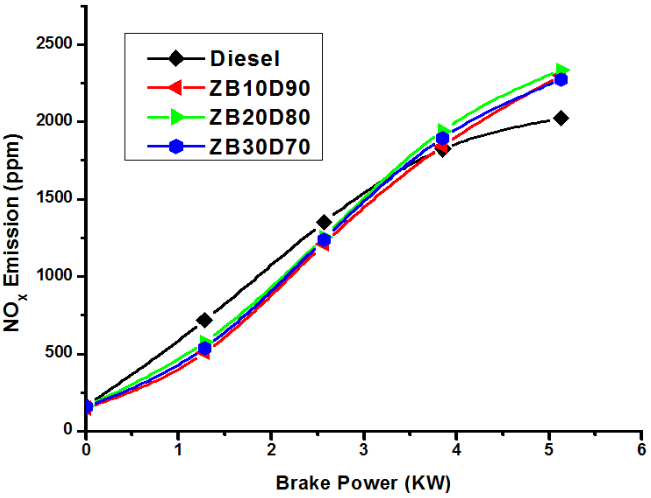

Fig. 9 Variation of NO_X with B.P

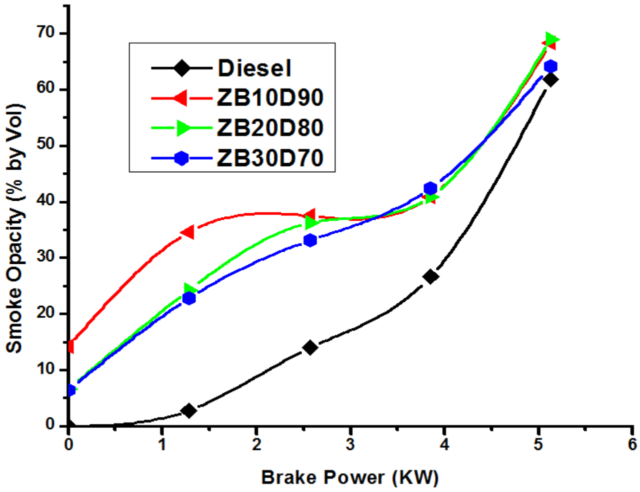

Fig. 10 Variation of Opacity with B.P

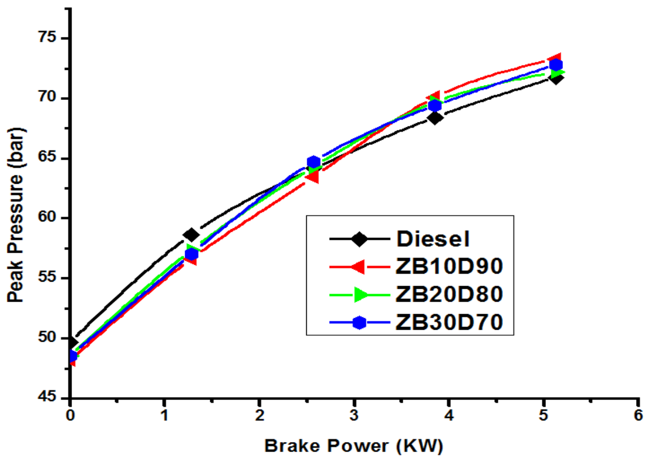

Fig. 11 Variation of Peak Pressure with B.P

C. Characteristics of Combustion

The relation between brake power and cylinder peak pressure is explained by figure 11. As per the image, it has been long-established that the peak pressure steadily rises as the brake power increase. The peak pressure relies upon the quantity of fuel scorched in the premixed combustion zone and it is regulated by the ignition suspension period. At the conditions, initial load the peak pressure of pure diesel is more than that of biodiesel blends, but from 50% it is being enlarged than the pure diesel. this is due to the presence of oxygen atoms in biodiesel, hydrocarbons could achieve whole burning resulting in increased in-cylinder pressure. It can be noted that at full load condition, ZB30D70's peak pressure is 73 bar and is increased by 1.71% than that of fossil diesel to some extent.

The difference of extreme heat release rate with regard to rise in brake power for various blends of biodiesel and pure diesel was represented in figure 12. for all the test models, the release rate of maximum heat is progressively improved as the brake power rises, but at full load or a maximum brake power it was reduced dramatically, due to increased delay in ignition and decreased premixed combustion phase. Among all the biodiesel mixtures, the blend ZB30D70 is decreased by 5.04% when t is related to pure diesel and displays maximum release rate of heat, which is 40.90 J/^{0}CA.

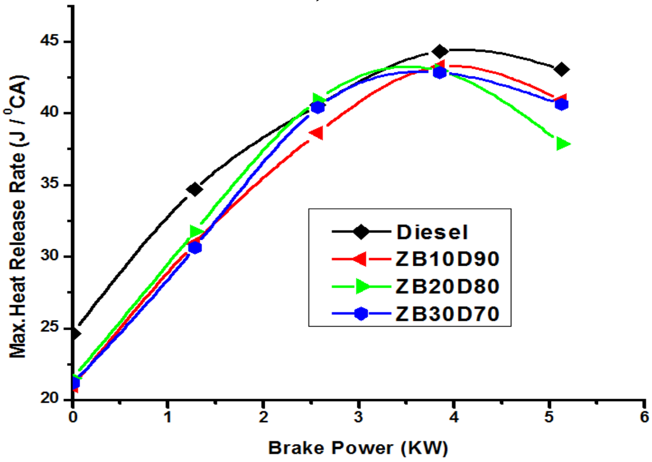

Fig. 12 Variation of Max.H.R rate with B.P

IV. CONCLUSIONS

A single cylinder four stroke compression ignition engine was functioned successfully on straight diesel and its mixtures with Manilkara Zapota methyl ester. The succeeding conclusions are made from the above investigational discussions and results:

1) With ZB20D80, BSFC was reduced by 7.69% at full load state when compared to fossil diesel.
2) At full load condition, the BTE was improved by 9.44% with ZB20D80 when compared to diesel.
3) The temperature of exhaust gas was reduced by 11.11% and is lower with ZB30D70 at full load condition when comparison is done with diesel fuel.
4) The CO percentage is quite low related to conservative diesel and it was decreased by 64% at full load condition with ZB30D70.
5) No important modification in the CO_2 percentage.
6) Compared to pure diesel with ZB30D70 at full load condition, HC percentage was slightly increased by 6.67%.

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7) The emission of NOx of all the biodiesel mixtures is more than that of diesel, but ZB30D70 displays less amount of NOx and is improved by 12.36% at full load condition when compared to diesel fuel.
8) ZB30D70 has recorded less percentage of smoke off all the biodiesel blends. The smoke percentage of ZB30D70 is increased slightly by 3.88% compared to fossil diesel at full load state.
9) The peak pressure of the blend ZB30D70 is 73 bars at full load condition and is improved by 1.71% than that of fossil diesel.
10) The blend ZB30D70 displays highest heat release rate of 40.90 J/^{0}CA and is decreased by 5.04% when compared to unadulterated diesel among all the biodiesel blends.

To conclude, it was determined that Manilkara Zapota seed is the most useful feed stock for the production of biodiesel and it could be used as ancillary fuel to decrease emissions in compression ignition engines and to advance the performance of the engine.

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