Experimental Investigation of Papaya Methyl Ester on Performance, combustion and emission characteristics of DI diesel engine

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***Abstract*—In this work an attempt has been made to experimentally investigate the engine characteristics of diesel engine fuelled with papaya seed oil. The biodiesel was prepared through trans-esterification and blended with conventional diesel fuel on volume basis. The BTE of the engine with B50 blend is increased by 3% when compared with diesel fuel. The emission parameters are significantly reduced such as CO, HC, smoke are reduced by 33%, 15%, and 12% respectively when compared to that of conventional diesel fuel, while NOx emission shows marginal increase compared to diesel fuel. The combustion characteristics of the diesel engine such as heat release rate, cylinder pressure are almost similar to that of diesel fuel.**

Keywords— Biodiesel, Papaya methyl ester, Diesel engine, Combustion, Emissions

I. INTRODUCTION

Due to the increasing concern about the fuel shortage and environmental protection several researches has been made on improving fuel economy and decreasing exhaust emission. Because of the limited resources of petroleum oil, development of alternative fuel engines without modification of existing engine is needed. Alternate fuel is usually clean compared with diesel and gasoline the combustion process [1]. The papaya oil produced from papaya seed, this oil is non edible, yellowish, opaque and sticky. Generally, diesel engines have polluted the environment through the exhaust emissions of nitrogen (NOx), Carbon dioxides (CO_2) and oxides of sulphur (SOx). Moreover, NOx and CO_2 are the greenhouse gases and SOx causes acid rain. In other hand, bio-fuels appear to be a potential alternative greener energy substitute for fossil fuels [2-5]. It is renewable and available throughout the world. Due to its oxygen content bio-fuels produces complete combustion in comparison with conventional diesel fuel. Further, the environmental benefit is another motivation factor due to a lesser greenhouse effect, less air pollution, less contamination of water and soil and a reduced health risk. Bio-fuel contains less aromatic content and is practically sulphur free, thus the issue of acid rain is therefore, amended [6-9]. The properties of diesel fuel and papaya bio-diesel used in this investigation is shown in table 1. Papaya oil ($C_{17}H_{34}O_2$) is a pure substance however; diesel fuel is a complex mixture of large number of hydro carbons (such as C_3-C_{25} Hydro carbons). For this reason its fuel properties can change depending on the proportion of hydro carbon types used in the fuel mixture. Bio-fuels come from a variety of sources such as animal fats and seed oils. Papaya seed is also a source of bio fuel due its properties comparable to that of diesel; conventional seed oil in use today needs to be converted into bio-fuel, using Trans-esterification process. [10].

The objective of this investigation was to identify a suitable alternative fuel with better combustion characteristic and also to reduce emissions of DI diesel engines. The bio-diesel was extracted by traditional base-catalyzed trans-esterification process. The experimental investigation was carried out on a single cylinder, four stroke, water cooled, DI diesel engine.

II. TRANS-ESTERIFICATION OF PAPAYA OIL

The process of transesterification to synthesis bio diesel entails an alcohol and catalyst wherein, the triglycerides with larger molecules are broken into smaller components, esters As such, in the current study, the extracted papaya oil was transesterified using KOH (potassium hydroxide) has catalyzed and methanol has solvent to produce papaya methyl ester (PME). For synthesizing one liter of PME 200 ml of menthol and 10 g of KOH was found in the required after the Trans-esterification process, the formed glycerol has been drained out and the left out methyl ester is washed with distilled water to remove the impurities and the remaining glycerol. Subsequently, the bio diesel is heated up to 100oC to remove the last traces of water. Finally, the fuel properties of PME were identified by ASTM standard method and are shown in the table 1. It is worthwhile to note that after the trans-esterification process all the properties of PME were found in the incompliance with biodiesel standards for the current experimental investigation. The fuel properties reveal that the raw papaya oil has higher viscosity and boiling point, which does not support its direct use in diesel engine. Therefore, it is essential to transesterify the extracted papaya oil in order so to reduce its viscosity, and bring it to the permissible biodiesel standard so as to make it feasible for diesel engine operation.

TABLE I. PROPERTIES OF PME AND DIESEL

Properties	**Papaya raw oil**	**B100**	**B50**	**Diesel**
Specific gravity @15c/15c	0.9211	0.8811	0.8506	0.836
Kinematic viscosity@40c in cst	36.47	4.52	3.63	3.6
Flash point	295 º c	159º c	86 º c	74º c
Fire point	308 º c	171º c	92º c	84º c
Gross calorific value in KJ/kg	41351	42429	43664	42700
Pour point	< -4º c	< -7º c	< -10º c	<-23º c
Density @15 c in kg/m³	920.3	880.2	849.8	822

III. EXPERIMENTAL SETUP

In this investigation, a single cylinder DI diesel engine was used, generally it is employed for marine, agriculture and power source application. It is coupled with eddy current dynamometer, with the help of the dynamometer varying the load 20, 40, 60, 80 and maximum load. The schematic view of the experimental setup is shown in figure 1. The specifications of the engine are furnished in the Table 2. The engine was started manually and fuel supplied to the engine. The exhaust emissions were measured using AVL di-gas analyzer. The combustion was measured by AVL combustion analyzer. The air cooled pressure transducer was mounted in the cylinder head and connected to charge amplifier and indimeter, the data's are recorded in the pc using indiwin software. Initially engine was started by sole fuel after reaching the steady state condition above mention parameter was recorded for every load. The same procedure was followed for all blends.

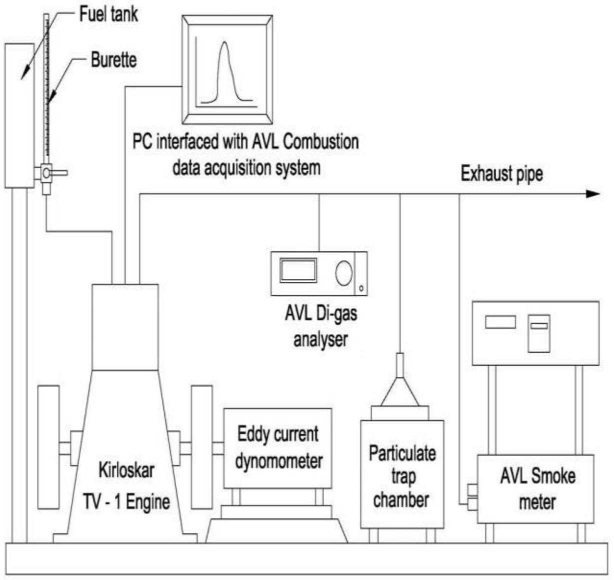

Fig. 1. Experimental Setup.

TABLE II. ENGINE SPECIFICATIONS

Specification of diesel engine used	
Make	Kirlosar-TV 1
General details	Four stroke, compression ignition, constant speed, vertical, water cooled, direct injection
Number of cylinder	One
Bore	87.5 mm
Stroke	110 mm
Compression ratio	17.5:1
Rated speed	1500 rpm
Rated output	5.2 kW
Injection Pressure	220 bar
Fuel injection timing	23° bTDC
Type of combustion chamber	Hemispherical open combustion chamber
Lubricating oil	SAE 40

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IV. RESULTS AND DISCUSSIONS

The operation of the engine was found to be very smooth throughout the rated load, without any operational problems for the hydrogen fuel. In the present section, the performance attributes such as brake thermal efficiency, indicated thermal efficiency and mechanical efficiency, and the emission characteristics such as NOx, CO, HC and smoke are plotted against brake power.

A. Performance Analysis

Fig. 2. shows the variation of brake thermal efficiency with brake power for PME blends. The thermal efficiency generally depends on the calorific value of the fuel and it is inversely proportional to the Specific fuel consumption. This parameter is more important than fuel consumption to compare the different fuels and its blends basically depending upon the heating value. Several authors reported in their study that the length of the carbon chain and the number of double bonds that influencing significant changes in the thermal efficiency. Among the studies of the different authors concluded that slight variation in the thermal efficiency was observed in the maximum brake power of the engine and there are no appreciable changes in the lower loads. With this token, in this case the calorific value of B50 is slightly higher than that of diesel and hence it provides better combustion. The BTE of the engine is improved when fuelled with PME blends. It can be observed from the figure that the thermal efficiency is 23.06% at maximum load for diesel fuel and for the B100 blend, it is 25.89%.

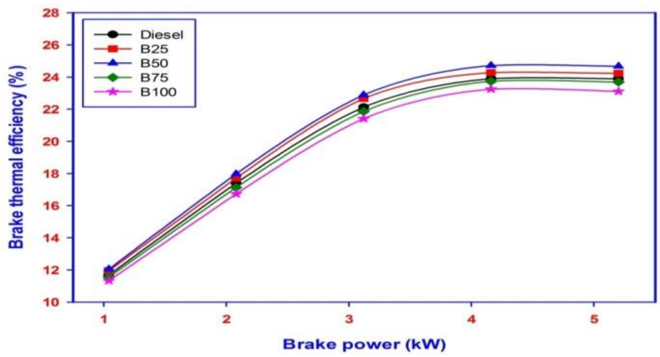

Fig. 2. Variation of brake thermal efficiency with brake power.

B. Emission Analysis

Fig. 3. shows the variation of NOx emission with brake power for PME blends and diesel fuel. NOx is formed by chain reactions involving nitrogen and oxygen in the air. These reactions depend especially on temperature arising from high activation energy. Since diesel engines always operate with excess air, NOx emissions are mainly a function of gas temperature and residence time [15]. At the same time, it is known that the NOx formation is dependent upon the volumetric efficiency [16 - 18]. In many studies, it was seen that the NOx emission varied linearly with the engine load, similar results were obtained in this study also. The additional oxygen content available in PME blends facilitates complete combustion thereby increasing the in-cylinder temperature which in turn increases the NOx emission for PME blends when compared to that of diesel fuel. In this case, due to higher heating value of blend B50 causes increase in premixed combustion and that favors the NOx formation.

The variation of CO emissions with load for PME blends and diesel fuel is shown in Fig. 4. The engine emits less CO using PME blends when compared to diesel fuel. The reason for this, that the additional oxygen content available in the PME blends mix well with air. i.e., the amount of the CO produced during combustion of PME blends may be converted into CO_2 by taking up the additional oxygen molecule present in the PME and thus reduced CO formation [11-14].

The smoke density variation of the engine for PME blends and diesel fuel is shown in Fig. 5. It is observed from the graph that the smoke decreases with PME blend when compared to that of diesel fuel. Smoke varies from 28 HSU at initial load to 90 HSU at maximum load for diesel fuel whereas it varies from 38 HSU at initial load to 94 HSU at maximum load for B100 blend of PME.

It is seen from the Fig. 6. that there is an important decrease in the HC emission with PME blends when compared to that of diesel fuel. The increased gas temperature and the cetane number were the reasons for this decrement. The high temperature of the burned gases precludes the condensation of the heaviest hydrocarbons in the sampling line, recommending proper conditions for HC emission analysis. Also, the higher oxygen content of the blended fuels compared to that of diesel fuel improves the combustion quality, thus leading to lower HC emission [19].

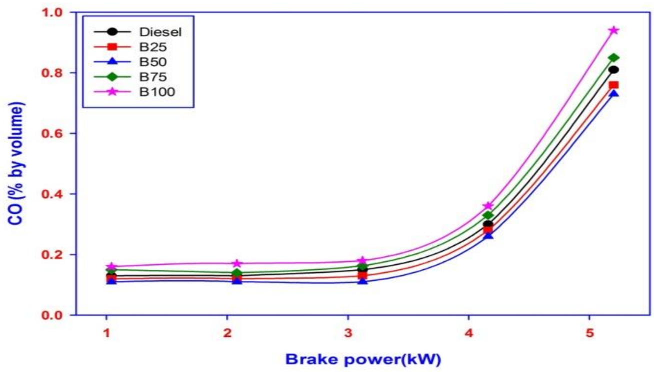

Fig. 3. Variation of carbon monoxide with brake power.

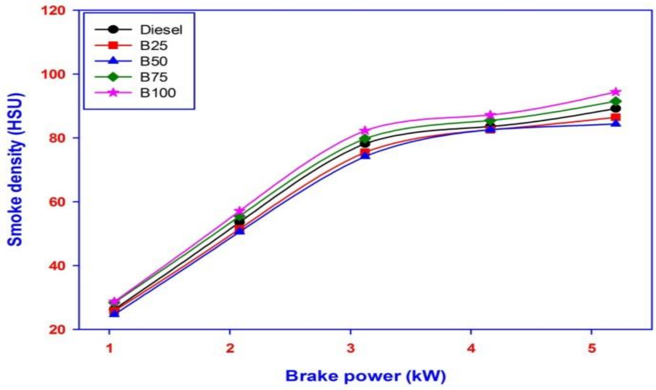

Fig. 4. Variation of smoke density with brake power.

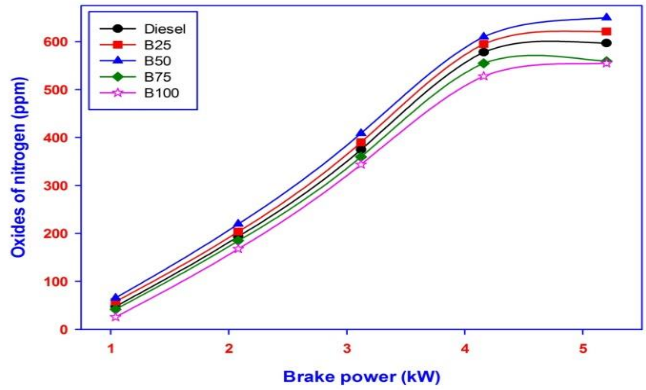

Fig. 5. Variation of oxides of nitrogen with brake power.

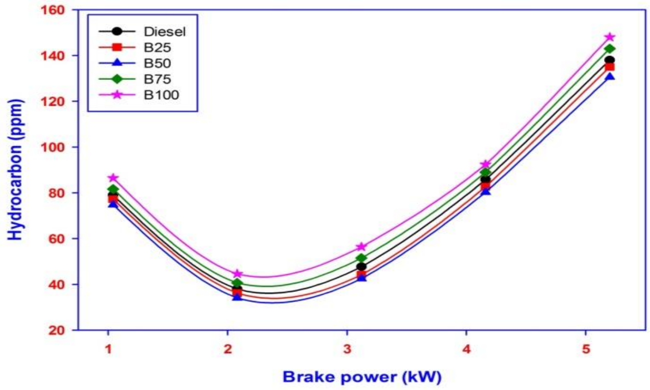

Fig. 6. Variation of hydrocarbon with brake power.

C. Combustion Analysis

Fig. 7. shows the variation of cylinder pressure with crank angle for PME blends and diesel fuel. From this figure, it is clear that the peak cylinder pressure is slightly increased for B50 blend. The cylinder pressure of a compression ignition engine mainly depends on the amount of fuel accumulated in the delay period and the combustion rate in the initial stages of premixed combustion. The combustion process is similar, consisting of a phase of premixed combustion following by a phase of diffusion combustion. Premixed combustion phase is controlled by the ignition delay period and the spray envelope of the injected fuel.

The variation of heat release rate with crank angle for PME blends is shown in figure 8. The heat release rate in the premixed combustion phase depends on the ignition delay, mixture formation and the combustion rate in the initial stages of combustion. From this figure, it is clear that the heat release rate of diesel fuel is slightly lower when operating with B50 blend of PME. The reason may probably be a shorter ignition delay exhibited and its blends causes the air-fuel mixture to accumulate in the combustion chamber. Further, due to entrapment of fuel/air mixture in the combustion chamber during the delay period, more quantity of fuel is burnt in the premixed combustion phase.

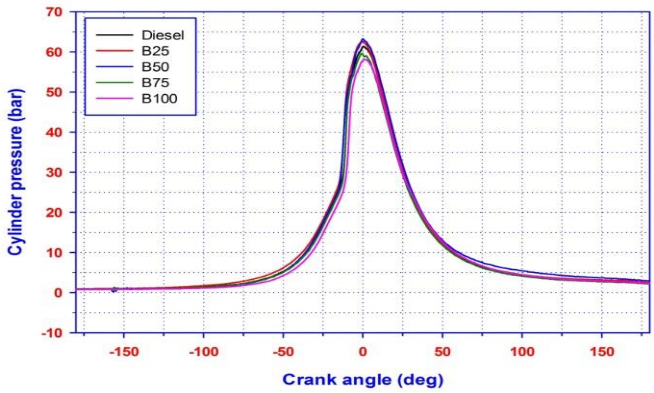

Fig. 7. Variation of cylinder pressure with crank angle.

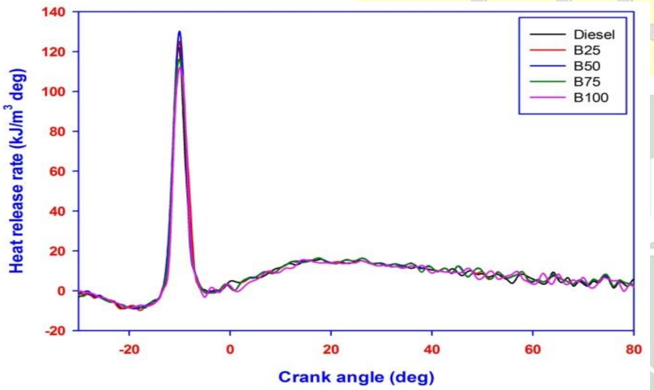

Fig. 8. Variation of heat release rate with crank angle.

CONCLUSION

In this experimental study, effects of transesterified papaya oil with standard injection timing were investigated. The most important conclusions are outlined as follows:

- It is observed that the bio-diesel from papaya oil can be used as a fuel in diesel engines without any problems in terms of engine performance.
- The properties of the bio-diesel are comparable to conventional diesel fuel. The physical properties like specific gravity, kinematic viscosity, calorific value, cetane number, flash point and fire point were determined.
- From the experimental investigation, it is observed that bio-diesel operating with standard injection timing show slight improvement in brake thermal efficiency when compared to that of diesel fuel. It shows 3% of increase when fuelled with B100 blend of PME. An increase in thermal efficiency at the expense of higher NOx is achieved for a constant speed diesel engine.
- At maximum load conditions, it reduces CO (carbon monoxide), HC (hydrocarbon) and smoke emission by 33%, 15%, and 12% respectively.

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