EXPERIMENTAL STUDIES ON BIODIESEL (PONGAMIA OIL) FUELLED DIRECT INJECTION DIESEL ENGINE WITH DIFFERENT TECHNIQUES

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Abstract - *Diesel engines are widely used in light, medium and heavy duty vehicles, load carriers, tractors, and power generation in heavy machinery, because of higher fuel efficiency and the ability for lean operation. Further, the lean burn capability helps to lower the carbon monoxide and hydro carbon emissions compared to those of a gasoline engine. However the emission of oxides of nitrogen and particulate matter are higher in a diesel engine. In the present work, the improvement in performance of the biodiesel fuelled (Pongamia methyl ester) diesel engine combustion and emission characteristics are experimentally investigated, varying the nozzle opening pressures, Ceramic coated piston (Titanium oxide coated piston) and Diethyl ether as fuel additives. Besides, comparing the measured performance and the exhaust emissions (exhaust smoke and oxides of nitrogen), a detailed combustion analysis of the acquired cylinder pressure histories on these samples has been attempted. From this analysis, the maximum reduction in exhaust smoke level is found to be 32 % and the CO level are decreased by 25 % with the 20% Pongamia methyl ester as compared to that of the diesel.*

Key Words: Pongamia oil, Titanium oxide, Transesterification, Diesel engine, emissions

1. INTRODUCTION

The ever increasing demand for petroleum based fuels and the uncertainty in their availability has been a matter of concern world over. The huge outflow of foreign exchange on one hand and increasing emissions causing environmental hazards on the other, have triggered interest in alternatives to gasoline and diesel. Oil provides energy for 95% of transportation and the demand continues to rise, particularly in rapidly developing countries like India and China. The requirement of gasoline and diesel is expected to be about 13 MMT and 66 MMT by 2011-2012. The domestic supply of crude oil in India will satisfy only about 22% of the demand and the rest will have to be met from imported crude oil. Crude oil prices and availability are subject to great volatility depending upon the international situation and relationships between the countries. Moreover, import of petroleum is a major strain on a country"s foreign exchange resource. Hence, steps are being taken to reduce dependence on oil imports.

1.1 Properties of Vegetable oil

The properties of vegetable oils fall within a narrow band and are close to those of diesel fuel. Vegetable oils have about 10 percent lesser heating value than diesel because of the presence of oxygen in their molecule. The kinematics viscosity is several times higher than diesel. This leads to pumping and atomization problems. They have a high carbon residue, indicated by the Conradson value and high viscosity, which are due to the large molecular mass and their chemical structure. They have poor volatility characteristics and hence are not suitable for spark ignition engines. By their properties, vegetable oils are suitable fuels only for compression ignition engines. In India, only non-edible oils can be considered seriously since the others are in great demand and are too expensive.

Pongamia pinnatta is medium sized tree and is found throughout India. The tree is drought resistant. Major producing countries are East Indies, Philippines, and India. The oil content varies from 27-39%. Its cake is used as pesticide and fertilizer. A thick yellowish-orange to brownish oil is extracted from seeds. Yields of 25% of volume are possible using a mechanical expeller. The oil has a bitter taste and a disagreeable aroma, thus it is not considered edible. In India, the oil is used as a fuel for cooking and lamps. The oil is also used as a lubricant, water-paint binder, pesticide, and in soap making and tanning industries. The oil is known to have value in herbal medicine for the treatment of rheumatism, as well as human and animal skin diseases. It is effective in enhancing the pigmentation of skin affected by leucoderma. The oil of Pongamia is also used as a substitute for diesel. Its flash point is 248°C as compared to 50°C for diesel, hence it is easy to store and handle. The kinematic viscosity of Pongamia oil is very high as compared to that of diesel.

In the present project work, the experiment is conducted on a direct injection diesel engine with Pongamia methyl ester and its diesel blends like B10, B20 and B100 with different nozzle opening pressures like 180 bar,200 bar and 220 bar, 500 micron thickness of TiO_2 coating on the piston crown . The setup has been developed for analyzing the performance, combustion and emission characteristics of DI diesel engines with Pongamia methyl ester. The combustion characteristics like cylinder pressure and, peak heat release heat release rate rate, ignition delay, combustion duration and the exhaust gas emissions of NOx, CO, CO_2, HC, smoke and O_2 have been analyzed under different load conditions.

2. METHODOLOGY

The step by step methodology that was followed is given by:

1. Selection of suitable vegetable oil methyl ester (Pongamia oil) for the study based on its availability.

2. Selection of a suitable single cylinder diesel engine and development of an experimental set-up with necessary instruments to study the performance, emission and combustion characteristics.

3. Fabrication of a set-up for the production of methyl ester of vegetable oils (biodiesel) by the transesterification process and preparation.

4. Conducting experiments with diesel and Pongamia methyl ester and its diesel blend with the base engine operation. And compare the performance, emission and combustion parameters with the diesel.

5. Conducting experiments with diesel and Pongamia methyl ester and its diesel blend with TiO_2 coated piston operation. And compare the performance, emission and combustion parameters with the base engine.

3. EXPERIMENTAL SETUP

An experimental set up was developed to conduct experiments on the selected compression ignition engine in different single fuel and dual fuel modes to evaluate performance, emission and combustion parameters at different operating conditions. This chapter discusses the details of the equipment used like engine, dynamometer, fuel and air flow measuring systems, emission measuring instruments and cylinder pressure measure systems etc.

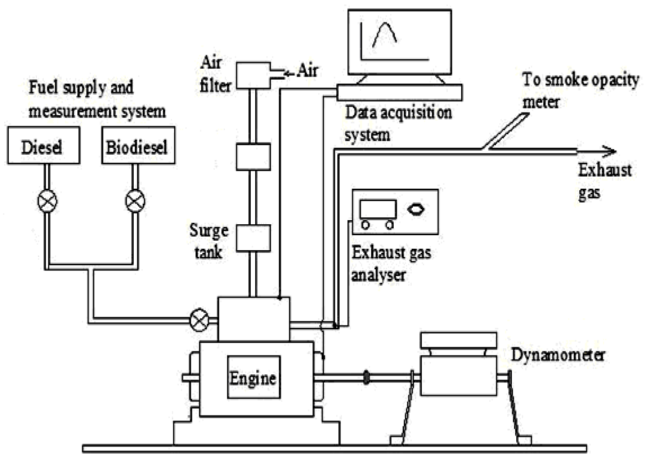

Fig 1: Schematic of experimental setup

Fig 2: Photographic views of base engine and TiO_2 coated piston

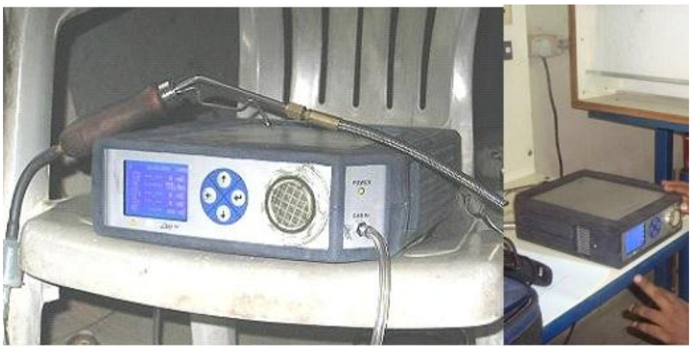

Fig 3: Photographic view of the exhaust gas analyser

Fig 4: Photographic view of the smoke meter

Pongamia Trees:

Milletia pinnata is a species of tree in the pea family, Fabaceae, native in tropical & temperate Asia including parts of India, China, Japan, Malaysia, Australia & Pacific islands. It is often known by the synonym Pongamia pinnata and it was moved to the genus Milletia only recently. Pongamia pinnata is one of the few nitrogen fixing trees (NFTS) to produce seeds containing 30-40% oil. It is often planted as an ornamental and shade tree but now-a-days it is considered as alternative source for Biodiesel. This species is commonly called pongam, karanja, or a derivation of these names.

Fig 5: Photographic view of Pongamia Tree with fruits


Fig 6: Photographic view of husk and seeds

TRANSESTERIFICATION OF PONGAMIA METHYL ESTER

Transesterification is an effective way to reduce the viscosity of the vegetable oils. During the process of Transesterification triglyceride of vegetable oil (Pongamia oil) react with alcohol (methanol/ethanol) in the presence of catalyst say NaOH or KOH and form glycerol and vegetable oil ester. A specified quantity of vegetable oil (1000ml) and methanol (450 ml) were taken in the round bottom flask. A few grams of (10gm) of NaOH were also added to the flask after starting the stirring process. The contents were heated up to 60°C and stirred vigorously for 45 minutes till the ester was formed. The mixture was cooled to room temperature and few drops of hydrochloric acid were added to neutralize it. Then the contents were washed with hot distilled water and allowed to settle overnight in a separator vessel. Two layers were formed, the bottom was glycerol and water and the top was the ester. The bottom layer was separated by pouring out through a separator valve fitted below. The product was heated for sufficient time at temperature over 100°C for expelling any remaining water. The resulting methyl ester is a transparent liquid with a pale yellow color.

Table 1: Comparsion of properties of diesel,Pongamia oil, Pongamia ester

Properties	**Diesel fuel**	**Pongamia oil**	**Pongamia ester**
Density (kg/m^3)	830	912	880
Kinematic Viscosity @ 40 °C (cSt)	3.01	41.06	4.25
Heating value MJ/kg)	42.5	34	38.3
Pour point (°C)	4	3	3
Flash point (°C)	50	241	180
Fire point (°C)	63	253	223
Cloud point (°C)	5	7	6
Cetane number	48	40	55.84
Carbon Residue	0.02	0.64	0.05
Ash Content (%, w/w)	0.01±0.0	0.005	0.03
Oxygen (%, w/w)	1.19	-	11

4. ANALYSIS AND PROCEDURE:

In this section the details of combustion and heat release analysis of experiments conducted in various modes of operation are presented. All the tests were conducted at the rated speed of 1500 rpm. All readings were taken only after the engine attained stable operation. The gas analyzers were switched on before starting the experiments to stabilize them before starting the measurements. All the instruments were periodically calibrated. The injector opening pressure and injection timing were kept constant at the rated value throughout the experiments. The following paragraphs describe the procedure adopted for the analysis of the experimental data obtained during this investigation.

PERFORMANCE PARAMETERS:

The performance characteristics are estimated from the measured
values

i) Brake thermal efficiency: (BTE) BTE =Output power/[FC*CV]
ii) Brake specific fuel consumption: (BSFC) BSFC = FC/BP

Brake specific energy consumption: (BSEC)

BSEC = BSFC x C.V [where C.V is the calorific value of the fuel]

iii) Fuel consumption : FC

FC = [known quantity of fuel consumed/time taken for the known quantity of the fuel consumed]* density of the fuel
Brake specific energy consumption: (BSEC) BSEC = BSFC x CV

iv) Brake power : (BP)

BP= W*N/C

where W is the load on the dynamometer, N is the speed of the engine and C is the dynamometer constant.

5. RESULTS AND DISCUSSIONS:

The present investigation concerns improvement in combustion, performance and emission characteristics of a single cylinder, four stroke, water cooled DI diesel engine with Pongamia methyl ester (PME) using different blends like B10,B20 and B100, various nozzle opening pressures, Titanium oxide coated piston (TiO2) have been investigated. The results of performance and emission parameters are based on the study of the combustion parameters, like ignition delay, cylinder pressure, rate of heat release and combustion duration; these have been measured and presented in the following sections.

TESTS WITH PONGAMIA METHYL ESTER BLENDS WITH DIESEL:

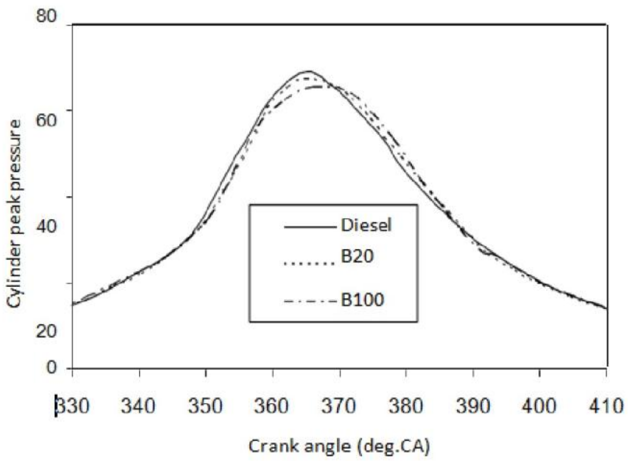

Chart 1: Variation of Cylinder pressure with CA at full load

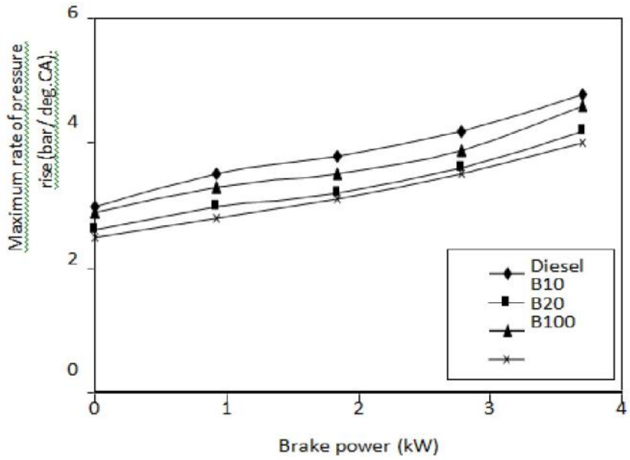

Chart 2: Maximum rate of pressure rise with BP

Smoke Emission:

The variation of smoke emissions at different engine load are presented below. The exhaust of the CI engines contains solid carbon particles that are generated in the fuel-rich zones within the cylinder during combustion. These are seen as exhaust smoke and cause an undesirable odorous pollution. The smoke emission increases with an increase in the load for all fuels. The smoke density for diesel is 3.6 BSU at full load, whereas for B20 and B100 it is 2.8 BSU and 2.4 BSU at full load. The reduction in smoke for biodiesel blends may be due to more oxygen atom present in the biodiesel, resulting in better combustion of biodiesel.

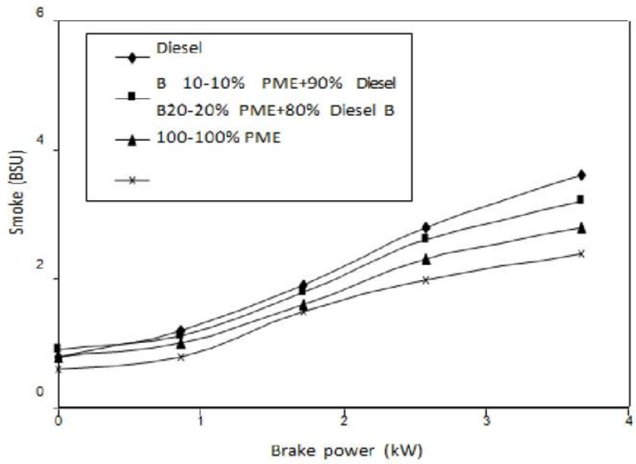

Chart 3: Variation of Smoke emissions with BP

TESTS WITH PONGAMIA METHYL ESTER USING TITANIUM OXIDE COATED PISTON:

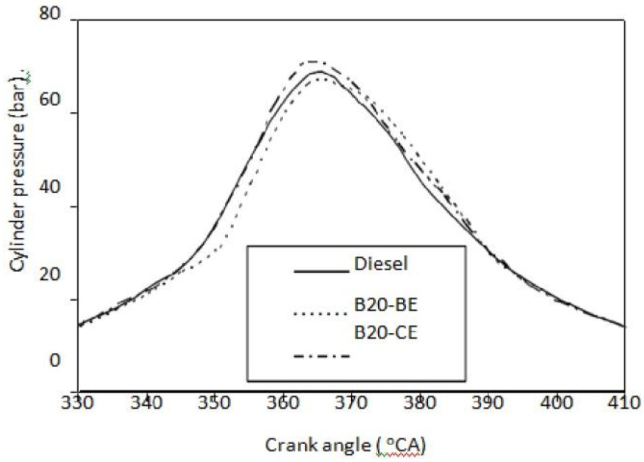

Chart 4: Variation of Cylinder pressure with CA at full load

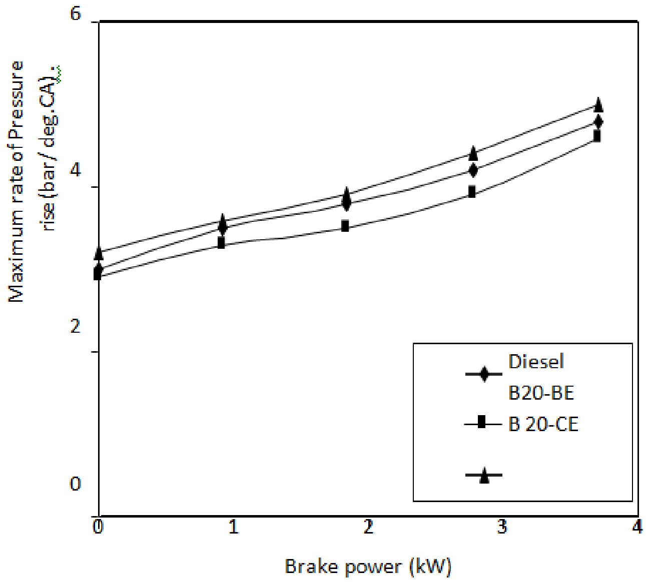

Chart 5: Maximum rate of pressure rise with BP

Smoke density:

The variations of smoke density for both the engine operations for all the test fuels are shown in Figure 6.42. The smoke densities decrease in CE was determined to be 25% for B20 at full load compared to that of the base engine. According to these values, a decrease in smoke density for all test fuels in the CE as a result of ceramic coating. However the smoke density of PME is lower than that of diesel for the engine operations. Lower smoke density of PME may be caused by higher oxygen present in the biodiesel. The oxygen content of fuel can contribute oxidation of biodiesel in fuel rich combustion zones, resulting in reduction in smoke density. The smoke value for the base engine with diesel and B20 are 3.6 BSU and 2.8 BSU respectively, whereas for the B20 with CE, it is 2.4 BSU at full load. The decrease in smoke for the CE may be due to better vaporization of biodiesel at higher combustion temperature and also more oxygen present in the biodiesel, resulting in complete combustion.

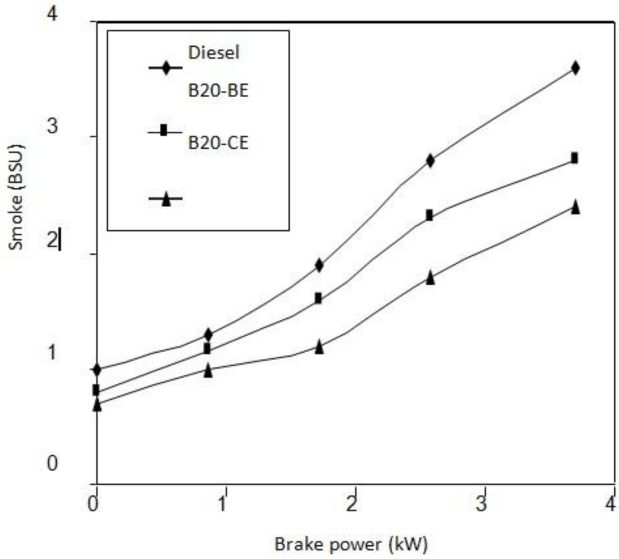

Chart 6: Variation of Smoke emissions with BP

Table 2: Overall comparisons of the experimental results of different injection pressures, TiO_2 coated piston

	Diesel-Base	B100-Base	B20-Base	B20- TiO_2
BTE (%)	30.45	26.62	28.72	30.94
CO(%Vol)	0.06	0.05	0.04	0.03
HC(ppm)	35	40	36	24
NO (ppm)	486	568	512	582
Smoke (BSU)	3.6	2.4	2.8	2.4
Peak.Pr (bar)	69	65	67	71
HRR (J/°CA)	63	55	58	66
MRPR(bar/ °CA	4.8	4.0	4.6	5
ID (° CA)	6	8	7.5	5
CD (° CA)	44	54	48	43

6. CONCLUSION:

From the above investigations, it can be observed that 20% Pogamia methyl ester (B20) with the TiO_2 coated piston gave better performance and reductions in exhaust emissions compared to 20%Pogamia methyl ester with various nozzle opening pressures and 10% oxygenated fuel additive Di-ethyl ether (DEE) due to better vaporization of B20 air fuel mixture by more heresulting in complete combustion of biodiesel diesel blends resulting in complete combustion of biodiesel diesel blends.

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REFERENCES:

1. Adnan Parlak, Halit Yasar, Can Hasimoglu and Ahmet Kolip (2005). "The effects of injection timing on NOx emissions of a low heat rejection indirect diesel injection engine", Applied thermal engineering, Vol.25, pp. 3042-3052.

2. Arun Balasubramanian.K (2012), "Dual Biodiesel Blends in Diesel Engine - Performance and Emission Analysis", European Journal of Scientific Research, Vol.75, No.3, pp. 400-408.

3. Bacon D. M., Brear. F., Moncrieff, I. D and Walker, K.L., (1981). "The use of vegetable oils in straight and modified form as diesel engine fuels", beyond the Energy crisis - Opportunity and Challenge Vol.III, Third International Conference on Energy use Management, Berlin (West),pp. 1525-33.

4.Banapurmath.N.R and P.G.Tewari, (2008). "Performance of a low heat rejection engine fuelled with low volatile Honge oil and its methyl ester", Proc.I MechE Vol.222, Part A. Journal of power and energy, pp. 323-330.

5. Bari.S., Lim.T.H. and Yu.C.W., (2002). "Effects of pre heating crude palm oil on injection system, performance and emission of a diesel engine", Renewable Energy, Vol.27, pp.339-351.

6. Barsic. N.J and Humke A.L., (1981). "Prospects of biodiesel production from vegetable oils in India", International Journal of Renewable and Sustainable Energy Reviews, Vol.9, pp. 339-351.

7. Barsic N.J. and Humke A.L, (1981). "Vegetable oils: diesel fuel supplements". J. Automotive Engineering, Vol.89, No.4, pp. 37-41.Beg.R.A and Rahman. M.S., (2002). "Performance studies on a semi- adiabatic diesel engine using vegetable oil as fuel", SAE paper No. 2002-01-2692, pp. 65-70.

BIOGRAPHIES

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