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Paper

Assessing Effect of Idling on Compression Ignition Engine Operated with Palm, Jatropha and Calophyllum Biodiesel Blends

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Abstract: Future lack of petroleum resources, price hike and environmental concerns have led to search for more environment friendly and renewable fuels. As an alternative fuel, biodiesel is considered as the most suitable alternative due to its environment friendly aspect and similar operation properties as diesel. In this study, Palm, Jatropha and Calophyllum biodiesel blends has been used to evaluate performance of a compression ignition engine operated at idling condition. Three idling modes were selected in which operating condition of engine were: a) 1000RPM 10% Load, b) 1200RPM 12% Load and c) 1500RPM and 15% Load. At high idling conditions biodiesel-diesel blends emit less HC and CO, but high amount of NO_X compared to diesel fuel. At high idling conditions fuel consumption of biodiesel-diesel blends deteriorate. CIB20 emitted lowest HC and CO, and highest NO_X at all idling modes.

Keywords: Engine; Idling; Fuel consumption; Emission.

1. Introduction

One of the major problems currently faced by the truck industry is the issue of engine idling. After driving for a certain period, it is mandatory for drivers to take a rest. During this time, the drivers keep the engine idling in order to maintain cab comfort and to provide power to the loads in the cab, such as heating, air conditioning, refrigerators, and microwaves [1] [6]. Studies indicate that long-haul trucks are idling for between 6 and 16 hours daily [7] [8]. During idling, the engine is not able to work at peak operating temperature and the combustion of fuel is incomplete, which leaves fuel residues in the exhaust and thus, emission levels increase [9]~[17]. Also, idling increases fuel consumption of engine. When the duration of idling is longer than 10 seconds the engine consumes more fuel compared with restarting it. The fuel consumed during 5 miles of driving is equivalent to just 10 minutes idling and 10 minutes of idling per day will consume more than 27 gallons of fuel per year. Idling fuel consumption is estimated to be approximately 0.8 – 2 billion gallons per year [12] [18]. Engines run at 30% efficiency (thermal) throughout highway operation, but at only 3 – 11% efficiency during idling [12]. In this paper, idling performance of a compression ignition engine operated with Palm, Jatropha and Calophyllum biodiesel blends has been reported.

Main objectives of this paper are:

a) To test engine performance at high idling conditions when the diesel engine is operated with Jatropha, Palm and *Calophyllum inophyllum* biodiesel-diesel blends.

b) To test emission of diesel engine operated with Jatropha, Palm and Calophyllum inophyllum biodiesel-diesel blends.

c) Compare these findings with the engine performance and emission of diesel engine operated with pure diesel fuel.

2. Selection of feedstock

Palm oil-Amongst the plant families, palms are the most popular and extensively cultivated. Elaeis guineensis Jacq is the most highly productive species. It can be cultivated in all tropical areas where weather is humid and hot like Malaysia and Indonesia [19]. This particular variety can annually produce 10 – 35 tonnes/ha of palm fruits. Oil is extracted from both the pulp and the seed. Oil palm trees are commercially cultivated to serve edible oil to the market [20].

Jatropha Curcas- Jatropha curcas is native to Central America and Mexico but widely found in wild or mountains in India, Africa and South-East Asia. It can be cultivated in all parts of India and well adapted dry and semi-dry conditions [21]. Jatropha curcas belongs to the genus Euphorbiaceae family which is a large, deciduous and soft wooded tree [22]. Oil is derived from the seed of jatropha plant. Each seed contains 30 – 40% oil [23].

Calophyllum inophyllum- *Calophyllum inophyllum* is a non-edible oilseed ornamental tree which belongs to Clu-

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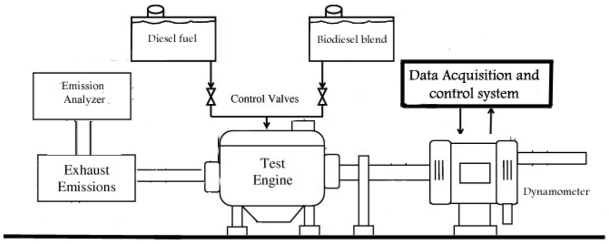

Figure 1: Schematic diagram of the engine test bed.

Table 1: Specifications of the engine.

Engine type		4 cylinder inline
Displacement	L	2.5
Cylinder bore x stroke	mm	92×96
Compression ratio		21:1
Maximum engine speed	rpm	4200
Maximum power	kW	55
Fuel system		Distribution type jet pump (indirect injection)
Lubrication System		Pressure feed
Combustion chamber		Swirl type
Cooling system		Radiator cooling

siaceae family [24] [25]. It is also known as Penaga Laut. It grows in coastal areas and areas where there are adjacent lowland forests. It grows in moderate conditions which have warm weathers and a minimum of 1000 – 4000mm rainfall is also needed per year. Its kernels have high oil content, the average oil yield is 4680kg – oil/ha.

3. Methodology

Viscosity, calorific value, density, oxidation stability, flash point, pour point, cloud point- these are the properties that determines the quality of the produced biodiesel. The important physical and chemical properties of the biodiesels were tested according to ASTM D6751 standard.

A 4-cylinder compression ignition engine was used in this experiment; its specifications were summarized in Table 1. Schematic diagram of the engine test is shown in Fig 1. At first the engine was warmed up for 5 minutes so that fluctuation of emissions can be avoided. Tests were carried out at three high idling modes- Mode 1 (1000 RPM and 10% load), Mode 2 (1200 RPM and 12% Load) and Mode 3 (1500 RPM and 15% Load). Loads were measured by dynamometer. In table 2, equipment used in the experiment is listed. For engine performance and exhaust emission test, every fuel sample has been tested three times and their average results were reported in this study.

The engine was connected with test bed and a computer data acquisition system. Therefore the test bed was connected to the data acquisition board, which collects signal, rectify, filter and convert the signal to the data to be read. The data acquisition board is connected to the laptop, where, user can monitor, control and analysis the data using software through REO-dCA controller.

Table 2: Equipment used in engine test.

Equipment Name	BOSCH BEA-350 exhaust gas analyzer
Measured	HC (parts per million or ppm)
	Carbon monoxide (percentage volume or %vol)
Equipment Name	AVL 4000 (Manufacturer: Graz/Austria)
Measured	NO_X (parts per million or ppm)
Equipment	Name DYNOMAX 2000 data control system
Measured	Brake Specific Fuel Consumption (BSFC)

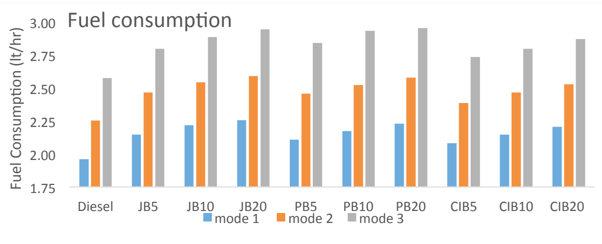

Figure 2: Fuel consumption of diesel and biodiesel-diesel blends at different idling modes.

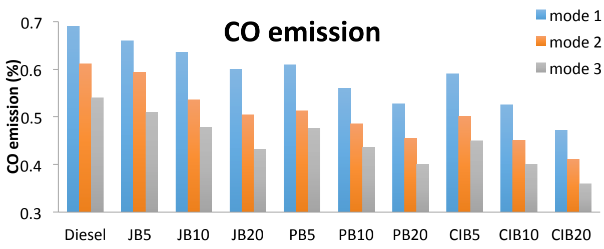

Figure 3: CO emission of diesel and biodiesel-diesel blends at different idling modes.

4. Results and discussion

Table 3 shows the important physico-chemical properties of produced biodiesel compared to diesel.

Figure 2 illustrates fuel consumption of diesel and biodiesel-diesel blends at different idling modes. Compared to all the tested fuels, fuel consumption of pure diesel was lowest at all. It can be seen that fuel consumption values are higher when biodiesel blended fuel is being used, which is supported by literature [26]. Biodiesel fuel is delivered into the engine on a volumetric basis per stroke; thus larger quantities of biodiesel are fed in to the engine. As a result, more biodiesel fuel is needed to produce same amount of power. For this reason, increase in blend percentages resulted in increase in fuel consumption for all the biodiesel-diesel blends. As idling speed increased fuel consumption also increased. This is also supported by other researchers also. When engine is idling at a faster speed, fuel consumption will be higher due to increase in fuel injection rate per second [13].

From Fig 3, it can be seen that, pure diesel fuel emits

Table 3: Major physico-chemical properties of produced biodiesel compared to diesel.

Properties	Units	Standards	ASTM D6751	Jatropha	Palm	Calophyllum	Diesel
Kinematic viscosity at 40 °C	mm2/s	ASTM D445	1.9-6	4.7227	4.6175	3.98	3.46
Density at 15 °C	kg/m3	ASTM D1298	860-900	865	861	867	833.1
Flash point	°C	ASTM D93	>130	182.5	188	178	77
Cloud point	°C	ASTM D2500	-3 to 12	5	6	11	8
Pour point	°C	ASTM D97	-15 to 10	3	2	4	6
Calorific value (Lower heating value)	MJ/kg	ASTM D240	-	39.8	39.5	41.2	44.664
Iodine value	g I/100 g	EN 14111	120 max	99	61	103	-
Acid value	mg KOH/g	ASTM D664	0.8 max	0.05	0.24	1.1	-
Oxidation stability	h	EN ISO 14112	3 min	3.7	3.3	6.3	110
Cetane number	-	ASTM D613	47 min	52	57	63	48

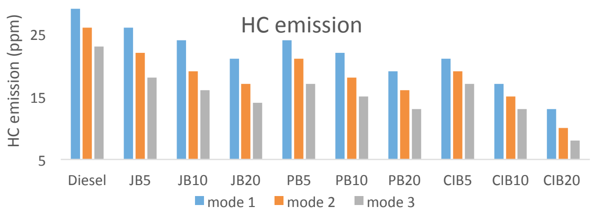

Figure 4: HC emission of diesel and biodiesel-diesel blends at different idling modes

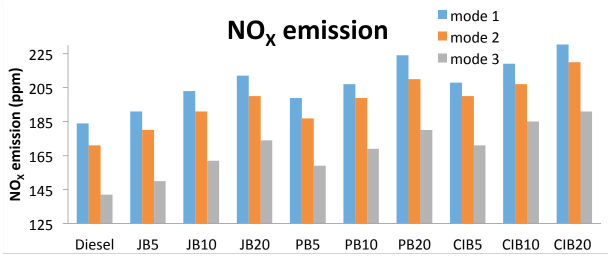

Figure 5: NO_X emission of diesel and biodiesel-diesel blends at different idling modes.

highest CO at all idling modes. As biodiesel has a higher cetane number, which results in the lower possibility of formation of rich fuel zone and thus reduces CO emissions [27] [28]. Also increase in oxygen content in biodiesel-diesel blends may be the reason behind the decrease in emission[29] [30]. With increase in speed CO emission decreased as better combustion occurred. CIB20 showed lowest CO emission at all idling modes as Calophyllum has the highest cetane number amongst the biodiesels tested.

Figure 4 represents HC emission at different idling modes for diesel and biodiesel-diesel blends. It can be seen that, diesel fuel emits highest amount of HC at all conditions and CIB20 blend emits lowest. Again, as there is higher oxygen concentration in the biodiesel-diesel blends which enhances the oxidation of unburned hydrocarbons, HC emission decreases with increase in percentages of biodiesel blends[31] [32]. Better combustion is achieved by biodiesel-diesel blends compared to conventional diesel fuel. Also, As biodiesel has higher cetane number compared to diesel fuel, combustion delay is less and thus HC emission is reduced while percentages of biodiesel in blends increases[33] [34]. Furthermore, increase in speed decreases HC emission for all tested fuel. This is due to the reason that increase in speed ensures better mixing of air and fuel.

Figure 5 illustrates NO_X emission of diesel and biodiesel-diesel blends at different idling modes. From this, it is seen that all the tested fuel showed same trend in emission. As speed increased NO_X emission decreased. With increase in speed, local adiabatic flame temperature decreased, as a result emission also decreased. From the Fig 5, conventional diesel fuel emits lowest amount of NO_X as combustion flame temperatures were higher with biodiesel. As biodiesel produces less soot, thus they have higher in-cylinder temperatures compared to conventional diesel fuel [35]. The delay between beginning of injection and beginning of ignition is known as ignition delay period. This period is related to the cetane number of the fuel, lower cetane leads to longer ignition delay. Usually, compared to petroleum diesel biodiesel fuels have much higher cetane numbers [35]. So, the ignition delay for biodiesels compared to petroleum diesel is short. A shorter ignition delay could allow the fuel mixture and initial combustion products to have a longer residence time at elevated temperature, thereby increasing NO_X formation.

5. Conclusion

Jatropha, Palm and *Calophyllum inophyllum* biodiesel diesel blends were used to operate a diesel engine at high idling conditions. The results obtained are given below:

- Properties of all the produced biodiesel were within ASTM D6751 limits.
- At high idling conditions biodiesel-diesel blends emit less HC and CO, but high amount of NO_X compared to diesel fuel.
- At high idling conditions fuel consumption of biodiesel-diesel blends deteriorate.
- CIB20 emitted lowest HC and CO, and highest NO_X at all idling modes.

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