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RUNNING A DIESEL ENGINE WITH BIODIESEL

Md. Ehsan[1], Rahat Miagi Taposh[2], Md. Mazharul Islam[2]

[1]Professor, Department of Mechanical Engineering, BUET, Dhaka.
[2]Graduates, Department of Mechanical Engineering, BUET, Dhaka.

ABSTRACT
The limited reserves and increasingly high price of the conventional fossil fuels are encouraging the use of various alternative fuels in internal combustion engines. Vegetable oils being renewable in nature could be a potential fuel for diesel engines. Among the various vegetable oils being tested palm oil is very promising for use in diesel engines. Palm oil was converted into biodiesel through trans-esterification reaction using methanol. Some properties of the biodiesel produced was measured and B20, B50 blends with diesel was prepared. The density and the heating value of biodiesel from palm oil was found to be close to those of diesel. This paper compares the performance of a small single cylinder water cooled diesel engine running on diesel, B20, B50 and B100. The performance of the engine running on B20 was very similar to diesel operation. The performance started detoriating with B50, but still within reasonable limit. The engine performance with B100 was not very satisfactory specially near rated load. The combustion process appeared to be retarded, increasing heat losses with exhaust and dropping the thermal efficiency. With present fuel costs it is still up to about 3 times more expensive to run a small diesel engine with biodiesel.

Keywords: Biodiesel, B100, B50, B20, Engine Performance, Alternative Fuel.

1. INTRODUCTION

The reserves of conventional liquid fossil fuels are limited and their increasingly higher prices are making them difficult to afford for many applications specially in the agricultural sector of developing countries. Many countries have been looking for alternative energy to substitute petroleum. Vegetable oil is one of the alternatives which can be used as fuel in diesel engines either in the form of straight vegetable oil, or in the form of ethyl or methyl ester. This paper presents a comparative performance testing of small single cylinder diesel engine run by biodiesel produced from Palm oil. Performance tests with biodiesel was conducted without any modification of the existing engine. Such diesel engines are widely used for irrigation and for standby power generation all over Bangladesh. The potential of biodiesel produced from Palm oil have been found to be a very promising fuel for diesel engines in a number of studies[1,2,3]. Although not a native plant, scattered cultivation of palm trees have started in different parts of Bangladesh and the bi-products from the vegetation have good demand in a number of chemical industries. Biodiesel from a number of other vegetations are also being tried out[4,5]. Using straight vegetable oil with diesel engines causes lot of deposition inside the engine and hampers long term engine operation [6]. Blends of chemically treaded vegetable oils are blended with diesel at different proportions termed as B20, B50, B100 etc. are being tried out in different types of diesel engine. B20 contains 20% biodiesel (B100) mixed with 80% conventional diesel by volume. This study compares some performance parameters of B20, B50, B100 mixtures of biodiesel with diesel alone based on short term engine-tests.

2. PRODUCING BIODIESEL FROM PALM OIL

Biodiesel fuel can be made from new or used vegetable oils and animal fats, which are nontoxic, biodegradable, renewable resources. Fats and oils are chemically reacted with an alcohol (methanol is the usual choice) to produce chemical compounds known as fatty acid methyl esters. Biodiesel is the name given to these esters when they're intended for use as fuel. Glycerol (used in pharmaceuticals and cosmetics, among other markets) is produced as a coproduct Biodiesel can be produced by a variety of esterification technologies. The oils and fats are filtered and preprocessed to remove water and contaminants. If free fatty acids are present, they can be removed or transformed into biodiesel using special pretreatment technologies[3]. The pretreated oils and fats are then mixed with an alcohol (usually methanol) and a catalyst (usually sodium hydroxide). The oil molecules (triglycerides) are broken apart and reformed into methylesters and glycerol, which are then separated from each other and purified[1]. Palm oil available in the market was collected. Presently this is mostly being imported from Malaysia as edible oil, but also has use in some cosmetic and toiletries industry.

2.1 Blending and Separation

During the esterification process of palm oil, first 200ml (99% pure) methanol was mixed with 3.5gm NaOH (96% pure). This mixture was shaked untill NaOH is dissolved completely. This solution is added with one liter of palm oil at a temperature of 60°C. The mixture is blended by a electric blending apparatus as shown in figure 1. The blending apparatus developed is capable of handling up to 5 liters of mixture at a time. After blending for 3 minutes (3 goes of 1 min each) this is then left for 24 hours to settle down. The mixture gradually settles in to two distinctive layers as shown in figure 2. The upper more transparent layer is B100 biodiesel and the lower translucent concentrated layer is glycerol. About 100 ml of glycerol is settled at the bottom along with about 1100ml B100 biodiesel. The heavier layer can be easily removed and the biodiesel is separated.

Fig 1: Blending setup

B100 just mixed B100 after 24 hours

Fig 2: Separation of glycerol layers after settling

2.1 Trans-esterification Reactions

Methyl esters derived from vegetable oil have good potential as an alternative diesel fuel. The cetane number, energy content., viscosity, and phase changes of biodiesel are similar to those of petroleum-based diesel fuel [3]. Biodiesel is produced by transesterification of large, branched triglycerides (TG) into smaller, straight-chain molecules of methyl esters, using an alkali or acid as catalyst[3]. There are three stepwise reactions with intermediate formation of diglycerides (DG) and monoglycerides (MG) resulting in the production of 3 mol of methyl esters (ME) and 1 mol of glycerol (GL) as follows .

The overall reactions are:

$$TG + 3ROH \xrightarrow{\text{Catalyst}} 3R'CO_2\text{-}R + GL$$

The stepwise reactions are:

$$TG + ROH \leftrightarrow DG + R'COOR$$

$$DG + ROH \leftrightarrow MG + R'COOR$$

$$MG + ROH \leftrightarrow GL + R'COOR$$

3. PROPERTIES OF BIODIESEL

A number of properties of the biodiesel (B100) produced are targeted to be studied. The calorific value and densities are essential for calculating primary engine performance parameters. The tests for determining the heating value was carried out using standard Bomb calorimeter method and the density at 20°C was measured. Figure shows the temperature rise in the Bomb Calorimeter for B100. From these results corresponding values of density and heating value of B20 and B50 mixtures with diesel fuel was calculated. Table-1 shows the property values of the biodiesel produced compared to diesel fuel. Density and heating valvues of palm biodiesel was found to be very close to ordinary diesel.

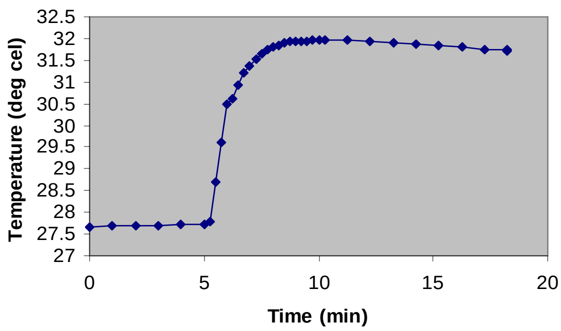

Fig 3: Measuring Heating Value of Biodiesel using Bomb Calorimeter

Table 1: Comparison of heating value and density of biodiesel produced from palm oil w.r.t. diesel fuel

Parameter	Diesel	Biodiesel
Calorific value (MJ/kg)	44	43 (B100)
Specific gravity (20°C)	0.851	0.830 (B100) 0.840 (B50) 0.846 (B20)

4. EXPERIMENTAL SETUP

A four-stroke, single cylinder, 903 cc, water-cooled diesel engine was tested at constant speed. The engine specification are given in table-2. Constant speed tests were carried out at rated 2200 rpm for variable loads, extending from 50% to 100% rated load. A hydraulic brake dynamometer directly coupled with the engine was used to load the engine. Load was varied by changing the water flow rate to the dynamometer. Fuel was supplied from externally installed tank, allowing volume measurement of fuel consumed. Temperatures were measured using K-type thermocouple. The experimental setup is shown in figure 4. First tests were carried out using diesel fuel. Tests were repeated for B20, B50 mixtures and B100 biodiesel.

Table 2: Engine specification

Engine type	1-cylinder, Horizontal, 4-stroke, Water-Cooled
Bore × Stroke	100mm×115mm
Compression ratio	20:1
Displacement Volm.	903 cc
Rated rpm	2200rpm
Rated power	11 kW (15 PS) for 12 hour
Fuel Tank	16 liters
Fuel injection Press.	13244 KPa
Fuel injection timing	17° B.T.D.C
Lubrication	Forced, SAE 40
Starting	Manual

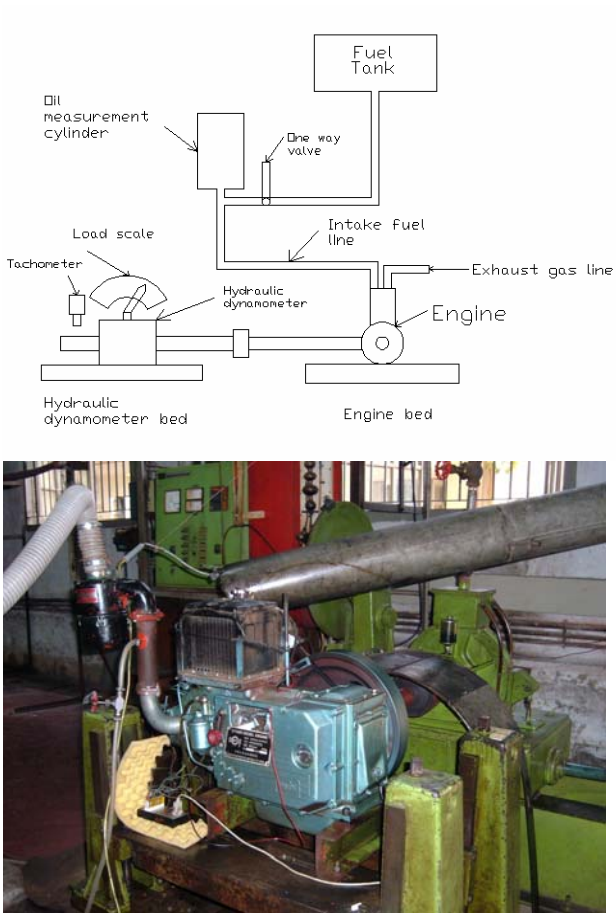

Fig 4: Experimental set up.

4. RESULTS AND DISCUSSION

Figure 6 shows the brake specific fuel consumption results over the load range for diesel with B20, B50 and B100. The variation of thermal efficiency is shown in figure 7 and figure 8 shows the temperature of the exhaust gases leaving the engine. Test results were derated as per BS5514 standard.

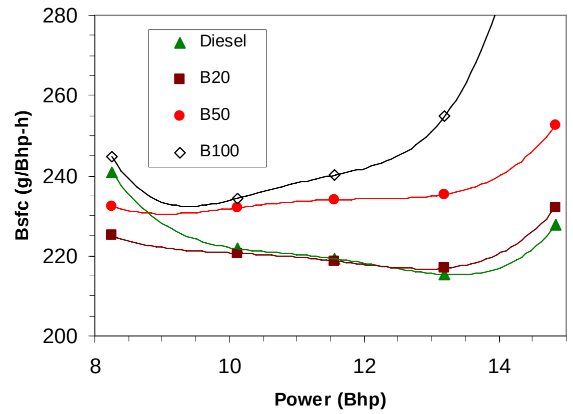

Fig 6: Variation of Bsfc for diesel, B20, B50, B100.

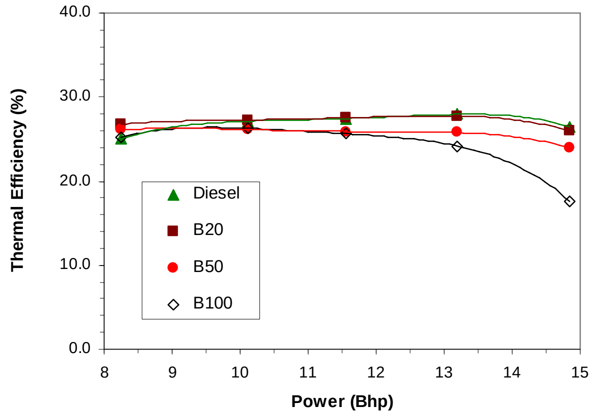

Fig 7: Variation of Bsfc for diesel, B20, B50, B100

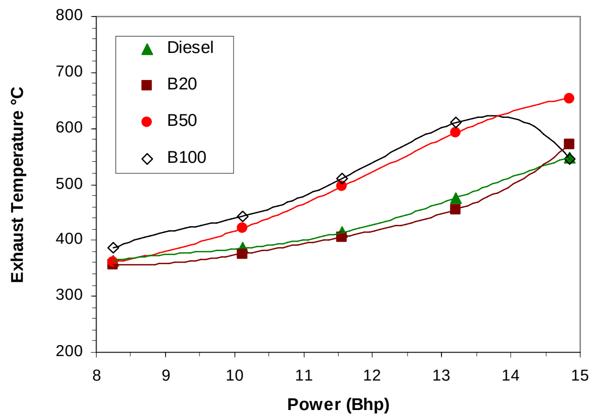

Fig 8: Variation of Exhaust gas temperatures.

The brake specific fuel consumption was measured to vary from 232 g/bhp-h at near 50% load and reduce to 215 g/bhp-h at rated capacity achieving a thermal efficiency of about 28%. Values are typical for diesel engines of this category and the maximum power attained was only slightly less than the manufacturer's specification. Using B20 did not show much difference in performance. The bsfc ranged from 225 - 232 g/bhp-h for B20. Since the heating is only slightly less, this achieved a very similar thermal efficiency. Close similarity in exhaust temperatures indicates very similar combustion. Results demonstrate that very little deviation of engine performance can be expected if B20 replaces diesel. Things start changing with B50, the bsfc ranging 232 - 252 g/bhp-h. Thermal efficiency drops by 2-3% reaching only 25% at rated load. The exhaust temperature increased by up to 60°C compared to diesel or B20. Higher exhaust temperatures but lower power output indicates late burning due to higher proportion of biodiesel. This would increase heat losses making the combustion a bit less efficient. Using biodiesel only (B100) is still capable of running the diesel engine although performance is detoriated. The burning process is retarded further limiting the peak power that could be attained efficiently. This is reduces down to 13 hp (about 80%) of the rated capacity. Beyond this the combustion is seriously hampered, unburned fuels causes the exhaust temperature to be decreased and thermal efficiency dropping to 17%. Changing the fuel injection timing for B100 may improve the situation to some extent, but this would compromise instant inter changeability to diesel fuel. Viscosity of biodiesel also may play a significant role here[7]. Using B100 alone may cause faster deposition of gum material inside the engine, but this is difficult to be verified from short term engine tests. Lubricating oil temperature attained in the engine using biodiesel were found to be a bit higher compated to diesel. Currently studies are in progress regarding viscosity and any possible contamination of lubricating oil by biodiesel.

5. COST OF RUUNING THE ENGINE

Table 3: Costs of running engine with Biodiesel

Fuel	Cost (Tk/liter)	At 50% of rated load Tk/Bhp-h (Tk/kWh)	At rated load Tk/Bhp-h (Tk/kWh)
Diesel	40	11.3 (15.4)	10.7 (14.5)
B20	59	15.6 (21.2)	16.1 (21.9)
B50	87	24.1 (32.8)	26.1 (35.5)
B100	134	39.5 (53.7)	56.4 (76.7)

Table 3 shows a summary of present costing of running a diesel engine with B20, B50 or B100 biodiesel derived from palm oil. High cost per liter of biodiesel is mainly contributed from higher price of edible oil and high cost of methanol used for the trans-esterification. The fuel cost is about 1.4, 2.1 and 3.3 times more expensive compared to diesel for B20, B50 and B100 respectively. Regarding cost per kWh of mechanical power generation this is about Tk 15/kWh for diesel, Tk 21/kWh for B20, Tk 35/kWh for B50 near rated load. For B100 at 50% load this about 53 Tk/kWh, but incomplete combustion caused it to rise to Tk 76/kWh near full load. The costing shows that using biodiesel is still very expensive with the current market price of diesel, however sharp rise of conventional fossil fuel prices or unavailability of diesel fuel may change the economics.

6. CONCLUSIONS

Experiments were conducted on a small four-stroke, single cylinder, water-cooled diesel engine and performance characteristics of the engine was studied using diesel and diesel-biodiesel blends as fuels. The following conclusions could be drawn from this experimental study :

- Biodiesel could be produced from palm oil using a trans-esterification process, relatively simply.
- It was very much possible to run the diesel engine with diesel-biodiesel blend or biodiesel alone as the fuel.
- The density and the heating value of biodiesel from palm oil was found to be close those of diesel.
- The performance of the engine running on B20 was very similar to diesel operation.
- The performance started detoriating with B50, but still within reasonable limit.
- The engine performance with B100 was not very satisfactory specially near rated load. The combustion process appeared to be retarded, increasing heat losses with exhaust and dropping the thermal efficiency.
- With present fuel costs it is still up to about 3 times more expensive to run a small diesel engine with biodiesel.

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