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PERFORMANCE AND EMISSION CHARACTERISTICS OF CI ENGINE FUELLED WITH NON EDIBLE VEGETABLE OIL AND DIESEL BLENDS

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Abstract

This study investigates performance and emission characteristics of a diesel engine which is fuelled with different blends of jatropha oil and diesel (10-50%). A single cylinder four stroke diesel engine was used for the experiments at various loads and speed of 1500 rpm. An AVL 5 gas analyzer and a smoke meter were used for the measurements of exhaust gas emissions. Engine performance (specific fuel consumption SFC, brake thermal efficiency, and exhaust gas temperature) and emissions (HC, CO, CO_2, NOx and Smoke Opacity) were measured to evaluate and compute the behaviour of the diesel engine running on biodiesel. The results showed that the brake thermal efficiency of diesel is higher at all loads. Among the blends maximum brake thermal efficiency and minimum specific fuel consumption were found for blends upto 20% Jatropha oil. The specific fuel consumption of the blend having 20% Jatropha oil and 80% diesel (B20) was found to be comparable with the conventional diesel. The optimum blend is found to be B20 as the CO_2 emissions were lesser than diesel while decrease in brake thermal efficiency is marginal.

Keywords: Diesel engine, Emission, Jatropha, Performance.

1. Introduction

Scientists around the world have explored several alternative energy resources, which have the potential to quench the ever-increasing energy thirst of today's population. The projected petroleum production in the country as given in eleventh five year plan is shown in Table 1. The production of crude oil in India is estimated to have a decreasing trend after the year 2010 as can be seen from Table 1. But there will be an

Nomenclatures

B10	10% jatropha oil and 90% diesel by volume
B20	20% jatropha oil and 80% diesel by volume
BkW	brake kilowatt
CO	Carbon monoxide
CO_2	Carbon dioxide
HC	Hydro Carbon
NOx	Oxides of nitrogen

an increase in the vehicle population every year which will demand an increase in crude oil imports. With this scenario the need for an alternate fuel arises to maintain the economy of the country. Biodiesel have received significant attention both as a possible renewable alternative fuel and as an additive to the existing petroleum-based fuels [1-4].

Table 1. Projected Production of Crude Oil of India in MMT (2007-2012).

Company	2007–08	2008–09	2009-10	2010-11	2011-12	Total
ONGC	27.16	28.00	29.00	28.53	27.37	140.06
OIL	3.50	3.55	3.73	3.91	4.30	18.99
Joint Venture	10.57	10.78	9.76	8.75	7.85	47.71
Total	41.23	42.33	42.49	41.19	39.52	206.76
Actual Production	34.12					

Source: Draft eleventh five year plan document

Anand et al. [1] investigated the effect of injecting the fuel at 200 and 250 bar on the performance and emission characteristics of a single cylinder diesel engine and reported a marginal decrease in brake thermal efficiency and an increase in particulate matter emissions for blends of jatropha methyl esters compared to diesel. Agarwal [2] reported that blending the vegetable oil with diesel and alcohol oxygenates have improved thermal efficiency than pure vegetable oil. Performance and emission characteristics have been investigated by Banapurmath et al. [3] on a diesel engine operating with different biofuels. Kegl [4] investigated the influence of biodiesel on the injection, spray, and engine characteristics to reduce harmful emissions in a bus diesel engine. Carraretto et al. [5] have bench-tested the diesel engines and then installed on urban buses for normal operation. Distances, fuel consumption and emissions have been monitored; in addition to devices wear and tear, oil and air. A significant increase of SFC over the entire speed range is registered with biodiesel (about +16% average), due to its lower LHV and greater density. Kalam and Masjuki [6] investigated the effect of anticorrosion additive in biodiesel. The experimental results reported by Laforgia and Ardito [7] on a diesel engine have shown an improvement of efficiency of about 10% with biodiesel.

Md. Nurun Nabi et al. [8] investigated the combustion and exhaust gas emission characteristics when the engine was fuelled with blends of methyl esters of neem oil and diesel. The optimum blend of biodiesel and diesel fuel, based on the trade-off of particulate matter decrease and NOx increase, was a 20/80 biodiesel/diesel fuel blend. After an injection (BOI) delay of 3^o NOx emissions reduced while maintaining emission reductions associated with fueling a diesel engine with a

20/80 biodiesel/diesel fuel blend. The retarded timing reduced the time for combustion to occur in the cylinder, reducing the peak pressures and temperatures that enhance the formation of NOx emissions. Canakcia et al. [9] used artificial neural network for analyzing and predicting the performance and exhaust emissions from diesel engines.

Blends of varying proportions of jatropha curcas oil and diesel were prepared, analyzed and compared with diesel fuel for the compression ignition (C.I.) engine by Pramanik [10]. Among the various blends, the blends containing up to 30% jatropha oil have viscosity values close to that of diesel fuel. The blend containing 40% vegetable oil has a viscosity slightly higher than that of diesel. Heating the blends further reduced the viscosity. The viscosity of the blends containing 70% and 60% vegetable oil became close to that of diesel in the temperature ranges of 70–75°C and 60–65°C, respectively. From the engine test results, It is established that up to 50% jatropha curcas oil can be substituted for diesel for use in C.I. engine without any major operational difficulties. 70–80% of diesel may be added to jatropha oil to bring the viscosity close to diesel fuel and thus blends containing 20–30% of jatropha oil can be used as engine fuel without preheating. From the properties of the blends it is observed that biodiesel containing more than 30% jatropha oil has high viscosity compared to diesel. A reasonably good thermal efficiency of 22.44% was also observed with the 50:50 J/D blend. The maximum thermal efficiency of 27.11% was achieved with diesel, whereas only 18.52% thermal efficiency was observed using jatropha curcas oil.

The emission test results reported by Wang et al. [11] have shown that the heavy trucks fueled by B35 emitted significantly lower particulate matter and moderately lower carbon monoxide and hydrocarbon than the same trucks fueled by diesel. The heavy trucks that were tested had performed well when the originally equipped compression-ignition engine (diesel engine) was fueled with B35 without any engine modifications. A significant increase of specific fuel consumption over the entire speed range with biodiesel was reported. Oxides of nitrogen (NOx) emissions from B35 and diesel however, were generally in the same level

Ejaz and Jamal [12] in their study concluded that chocking of injector nozzles occur after a long run when the engine was fuelled with biodiesel. Though many researchers [1-16] have taken efforts to address the issues of biodiesel, the technology is yet to be fully exploited.

This study is to determine the extent to which blending can be done with diesel without scarifying much in the performance and emission characteristics of a diesel engine when fuelled with these blends without any engine modifications.

2. Experimental Method

2.1. Properties of Jatropha and diesel oil blend

Raw jatropha curcas oil was purchased and the transesterification of the same was done in our laboratory by standard methods. Transesterified jatropha oil was blended with diesel oil in varying proportions with the intention of reducing its viscosity close to that of the diesel fuel. It is evident that blending of transesterified vegetable oil with the conventional diesel fuel would bring the viscosity close to diesel [10]. The required physical and chemical properties of the biodiesel thus prepared were found using standard methods. The blends prepared were stable under normal conditions. The important properties of the blends are shown in Table 2.

Table 2. Properties of Jatropha and Diesel Oil Blends.

S. No.	Blend	Kinematic Viscosity at 40°C (mm^2/s)	Flash Point (°C)	Specific Gravity	Calorific Value (kJ/kg)
1.	B10	4.9	59	0.865	43647
2.	B20	5.2	65	0.868	43093
3.	B30	5.4	78	0.872	42207
4.	B40	5.6	80	0.876	41542
5.	B50	5.9	94	0.882	40877
6.	Diesel	4.0	50	0.853	44755

When compared with the properties of the mineral diesel oil the results show that the calorific value of all the blends was lower than diesel oil. However the kinematic viscosity, specific gravity and the flash point were higher.

2.2. Methodology

A single cylinder, air-cooled, four-stroke, direct injection diesel engine was used for the present study. The schematic arrangement of the experimental setup is shown in Fig. 1.

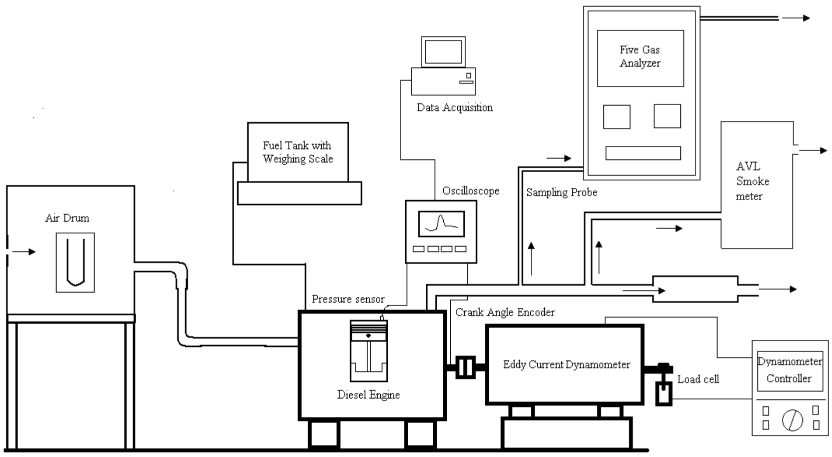

Fig. 1. Schematic of the Experimental Setup.

Cooling of the engine was accomplished by a fan attached to the engine. The engine was loaded by a powermag make eddy current dynamometer with electronic torque exciter. A load cell RS232 from Essae Teraoka limited was purchased and attached with the dynamometer for the measurement of the torque. The load on the engine was varied with the help of the controller provided with the dynamometer. Fuel flow rates were measured using the standard burette apparatus. Exhaust gas temperature was measured using the calibrated non contact infrared temperature measuring instrument. An AVL smoke meter and exhaust gas analyzer were used for the measurement of NOx, CO_2, CO, HC and smoke opacity respectively. Technical details of the engine are given in Table 3.

Table 3. Engine Specifications.

Make & Type	Kirloskar, Air cooled diesel engine
Number of cylinder	1
Stroke x Bore (mm)	87.5×110
Compression Ratio	17.5:1
Rated speed (rpm)	1500
Brake Power (kW)	4.4

The engine was started and run at no load at a rated speed of 1500 rpm. It was run at this speed for few minutes to attain steady state and then loaded gradually from no load to full load using the eddy current dynamometer.

2.3. Testing procedure

Experiments were conducted with esterified jatropha oil and diesel blends having 10%, 20%, 30%, 40% and 50% (B10-B50) esterified jatropha oil on volume basis at different load levels. Tests of engine performance on pure diesel were also conducted as a basis for comparison. The percentage of blend and load, were varied and engine performance measurements such as brake specific fuel consumption, air flow rate, and exhaust gas temperature and emissions were measured to evaluate and compute the behaviour of the diesel engine. Each time the engine was run at least for few minutes to attain steady state before the measurements were made. The experiments were repeated thrice and the average values were taken for performance and emission measurements.

3. Results and Discussion

A series of engine tests were carried out using diesel and biodiesel to find out the effect of various blends on the performance and emission characteristics of the engine. Investigations are carried out on the engine mainly to study the effect of specific fuel consumption, brake thermal efficiency, exhaust gas temperature and emissions such as NOx, CO, CO_2, HC and smoke opacity. It was found that the specific fuel consumption decreases from 0.649 to 0.336 kg/kW-hr at varying loads in the range of 0 – 3.9 BkW while Pramanik [10] reported a decrease in SFC from 0.693 to 0.332 kg/kW-hr. The brake thermal efficiency varies from 0-29.39% in the load range of 0-3.9 BkW while Pramanik [10] reported a maximum brake thermal efficiency of 27.11% for a load range of 0 – 3.078 BkW in his studies on a single cylinder diesel engine coupled with a hydraulic dynamometer. Exhaust gas temperature and NOx emission increases with increase in BkW for all the cases. NOx emission reaches a maximum of 1656 ppm for a blend of 50% at full load while a maximum of 1800 ppm for biodiesel was reported in the literature by the researchers[5]. These trends and the variations in the fuel properties such as viscosity and density for various blends are in accordance with the findings of many such researchers [5-10]. A detailed discussion on the NOx, CO,

CO_2, HC and smoke opacity were presented here under to understand the behaviour of the engine running on biodiesel.

3.1. Engine performance

Figure 2 shows the variation of brake specific fuel consumption of diesel and various blends of Jatropha and diesel oil at different loads. It is found that the specific fuel consumption for the blend B20 is close to diesel. However if the concentration of jatropha oil in the blend is more than 30% the specific fuel consumption was found to be higher than diesel at all loads. This is because of the combined effects of lower heating value and the higher fuel flow rate due to high density of the blends. Higher proportions of jatropha oil in the blends increases the viscosity which in turn increased the specific fuel consumption due to poor atomization of the fuel.

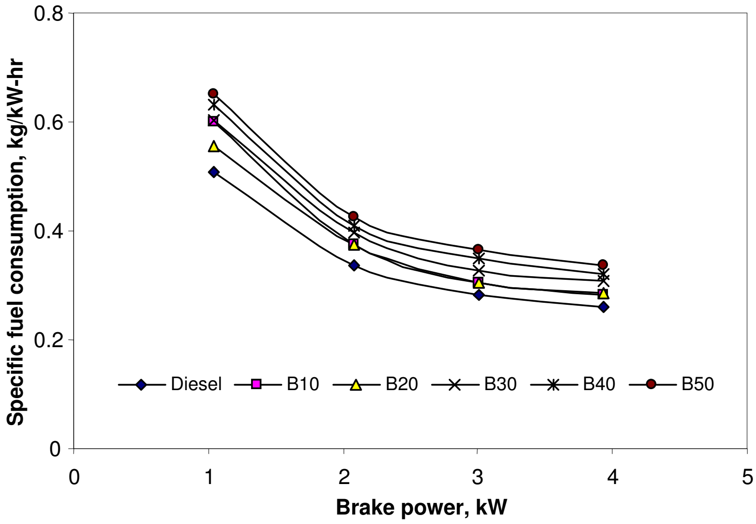

Fig. 2. Variation of Specific Fuel Consumption with Brake Power.

The variation of brake thermal efficiency of the engine with various blends is shown in Fig. 3 and compared with the brake thermal efficiency obtained with diesel. It was observed that brake thermal efficiencies of all the blends were found to be lower at all load levels. Among the blends B20 is found to have the maximum thermal efficiency of 29.40% at a brake power of 3.9 kW while for diesel it was 30.9% and for B50 it decreased to 26.1%. It was observed that as the proportion of jatropha oil in the blends increases the thermal efficiency decreases. The decrease in brake thermal efficiency with increase in jatropha oil concentration is due to the poor atomization of the blends due to their higher viscosity.

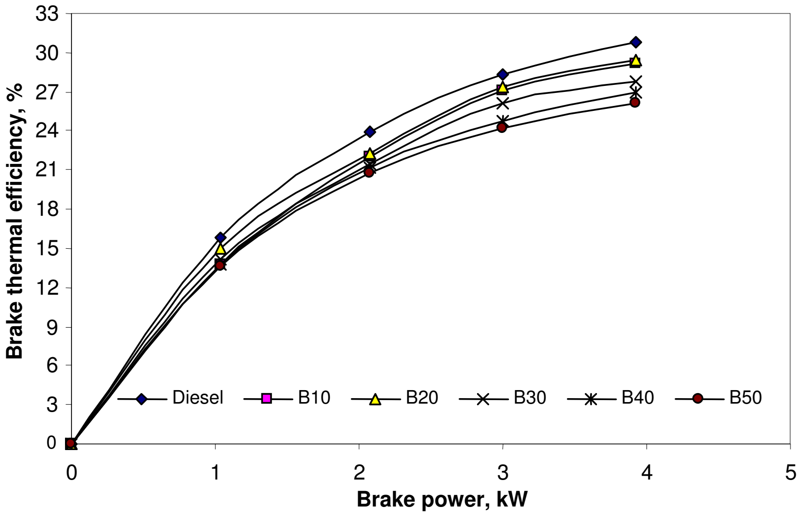

Fig. 3. Variation of Brake Thermal Efficiency with Brake Power.

Figure 4 shows the variation of exhaust gas temperature with load for various blends and diesel. The results show that the exhaust gas temperature increases with increase in brake power for all blends. At all loads, diesel was found to have the lowest temperature and the temperatures for various blends show an upward trend with increasing concentration of jatropha oil in the blends. The biodiesel contains oxygen which enables the combustion process and hence the exhaust gas temperatures are higher. Moreover the engine being air cooled runs hotter which resulted in higher exhaust gas temperatures.

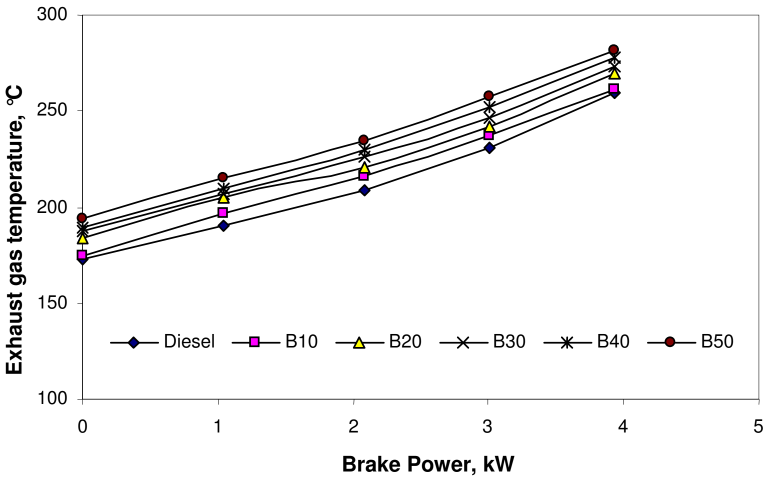

Fig. 4. Variation of Exhaust Gas Temperature with Load.

3.2. Engine emission

The variation of smoke opacity with brake power is shown in Fig. 5. It was observed that the smoke opacity of the exhaust gas increases with increase in load for all the blends. It also shows that the smoke opacity increases with the concentration of jatropha oil in the blends. This is caused mainly due to the poor atomization and combustion because of the higher viscosity of the blends. The opacity for diesel showed a similar trend as that of the blends, however the values were comparatively lower at all loads.

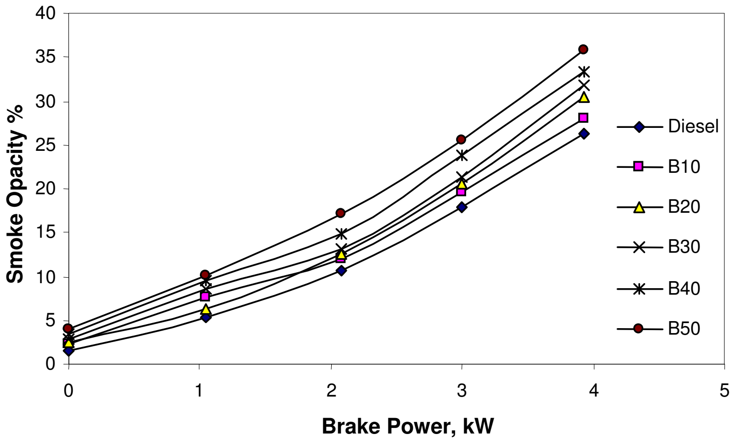

Fig. 5. Variation of Smoke Opacity with Brake Power.

Figure 6 shows the emission levels of CO_2 for various blends and diesel. Test measurements reveals that the CO_2 emission for all blends were less as compared to diesel at all loads. The rising trend of CO_2 emission with load is due to the higher fuel entry as the load increases. Biofuels contain lower carbon content as compared to diesel and hence the CO_2 emission is comparatively lower.

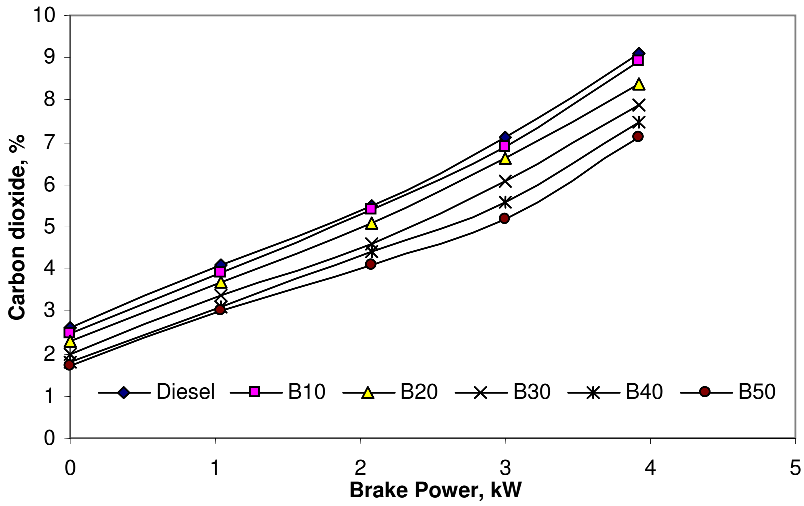

Fig. 6. Variation of Carbon Dioxide with Brake Power.

The variation of NOx emission for different blends is indicated in Fig. 7. The NOx emission for diesel and all the blends followed an increasing trend with respect to load. For the blends an increase in the emission was found at all loads when compared to diesel. NOx is formed generally at high temperatures. Since the exhaust gas temperatures are higher the NOx emissions are also higher.

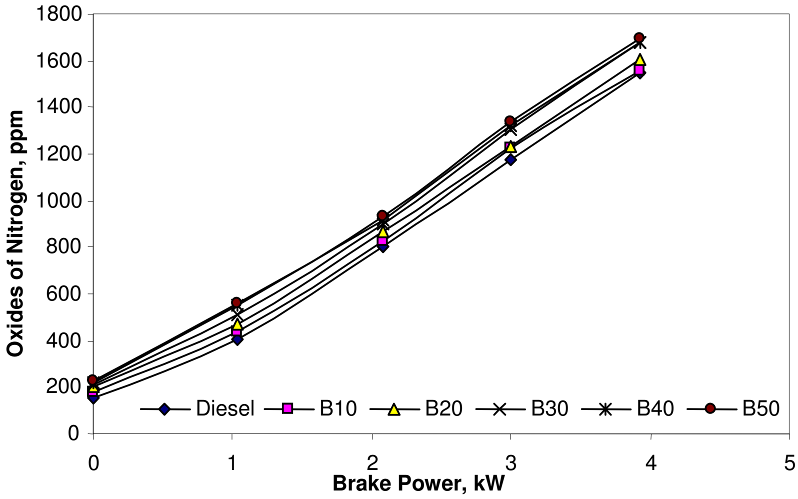

Fig. 7. Variation of Oxides of Nitrogen with Brake Power.

The variation of CO emission with brake power is shown in Fig. 8. It was observed that the engine emits more CO for diesel at part load conditions when compared to the blends. But as the proportion of jatropha oil in the blend increases the percentage of emission decreases. However the percentage variation of carbon monoxide for all the blends when compared with base line diesel is very much less.

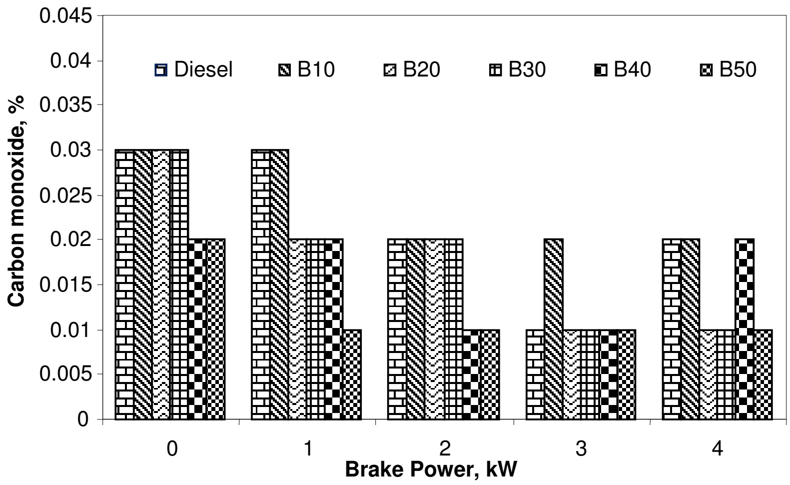

Fig. 8. Variation of CO with Brake Power.

The HC emission variation for different blends is indicated in Fig. 9. It was observed that the HC emission decreased up to a load of 2.1 kW and then increased slightly with further increase in load for diesel. The HC emission for the blends also followed a similar trend but comparatively the values were lower. The presence of oxygen in the jatropha oil aids combustion and hence the hydrocarbon emission reduced. However at higher loads the effects of viscosity have increased these emission levels for the blends.

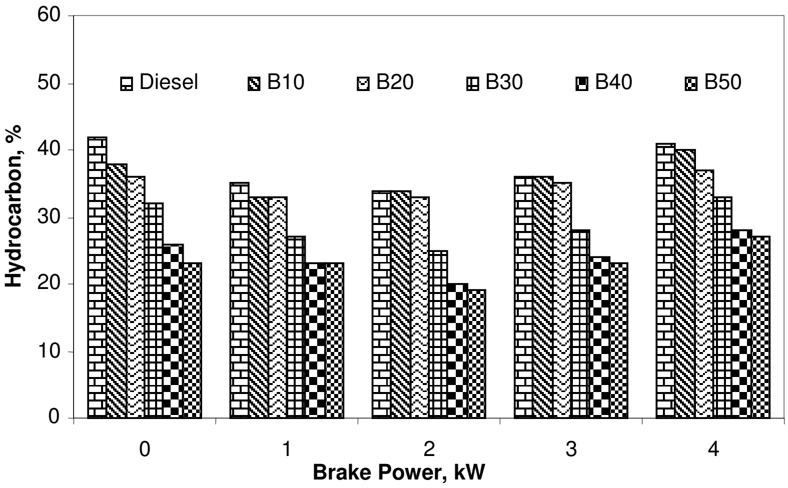

Fig. 9. Variation of Unburned HC with Brake Power.

4. Conclusions

Engine performance and emission results of blends of transesterified jatropha oil and diesel were compared with the results obtained with mineral diesel. The following are the major conclusions that are drawn.

- The specific fuel consumption is slightly higher than diesel for B20 but closer to diesel among all the blends. Blends up to 20% substantially reduce CO_2 emissions with a marginal decrease in brake thermal efficiency.
- The engine being air cooled the exhaust gas temperatures are higher, which in turn increased the NOx emissions.
- The smoke opacity is found to be higher than diesel for all blends due to their higher viscosity and density which led to poor atomization during combustion.
- A maximum brake thermal efficiency of 29.4% was achieved for B20 while for diesel it was 30.9% for the same power output. Experimental investigations show that blending of jatropha methyl esters up to 20 % with diesel for use in an unmodified diesel engine is viable.

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