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EFFECT OF LOAD ON THE PERFORMANCE OF A CI ENGINE FUELLED WITH PALM KERNEL OIL, CASTOR OIL BIODIESELS AND THEIR BLENDS WITH PETROLEUM DIESEL.

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ABSTRACT: The effect of load on the performance of a CI engine fuelled with palm kernel oil, castor oil biodiesels and their blends with petroleum diesel. Palm kernel and castor biodiesel were produced from their respective oils by trans-esterification process. Castor oil had high acid value of about 4.5mgKOH/g which needed pretreatment to reduce acid value to recommended value of 0.5 mgKOH/g and this was done through acid catalysis. The biodiesels were then blended with petroleum diesel in ratios of B10 to B90. These blends were then tested for chemo- physical properties, emission characteristics and engine performance analysis. The results of the test show that torque increased with load for B0-B20 while for B30-B90, it decreased; break power decreased with increased load as percentage of biodiesel increased in blends while it increased for B0-B20, BTE and BSEC increased with load while BTE decreased with load for all fuel samples; the emissions (H/C, CO, NOx, smoke opacity) decreased with increased load for all the fuel samples except for pk100 for which all the emissions increased with increase in speed. Generally, from the analysis carried out, it can be concluded that petroleum diesel (B0), B10, B20 and B30 are similar in performance and performed better averagely than others and, therefore, can be recommended for use in CI engines.

Index Terms: Biodiesel, Transesterification, Acid-catalysis, chemo-physical properties, castor oil, palm kernel oil.

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INTRODUCTION

It is no longer news that the world needs some more energy sources. This has become even more so as the anticipated problems and consequences associated with fossil fuels have started raising their ugly heads; the exhausting fossil fuels such as petrol, diesel, kerosene and gas. Other problems associated with fossil fuels include high cost of fuel, the many environmental consequences associated with them; environmental pollution, land degradation, erosion etc. All these have justified the quest for new energy sources.

Biodiesel stands out among all the renewable sources like wind energy, solar energy, natural gas.. Although, biodiesel still has its drawbacks, the advantages seem to outweigh the disadvantages. Animal fats, vegetable seed oils, waste frying oil, tall oil, fungi and algae etc, are used for ots production. A renewable source of energy, non-toxic, and biodegradable, available to be implemented immediately, with a non-complex technology. Vegetable oils as potential biodiesel fuels possess similar characteristics with fossil fuels but have attendant difficulties due to high viscosities and the poly-unsaturated nature of the bond structures.

Vegetable oil can be modified by a process known as transesterification into what is called biodiesel which overcomes those challenges associated with vegetable oils. Other processes like pyrolysis or thermal cracking and micro-emulsification can be employed to produce biodiesel from vegetable oils. Further property improvement could be achieved through blending of the biodiesel with petroleum diesel. Blending of one biodiesel with petroleum diesel is most commonly found in literatures however a number of authors have conducted studies on blending of two or more biodiesels with petroleum diesel Raheman et al [15] who carried out a research on performance of a diesel engine with blends of biodiesel (from a mixture of oils) and high-speed diesel. The research involved the evaluation of a 10.3-kW single-cylinder water-cooled direct-injection diesel engine using blends of biodiesel (B10 and B20) obtained from a mixture of mahua and simarouba oils (50:50) with high-speed diesel (HSD). Brake specific fuel consumption, brake thermal efficiency, and exhaust gas temperature and emissions such as CO, HC, and NO_x. BSFC, were found to increase with an increase in proportion of biodiesel in the fuel blends with HSD. BSFC increased with the increase in biodiesel percentage in the blends while it decreased sharply with increase in engine load for all the fuels tested due to relatively less amount of heat losses at higher loads. The BTE improved with the engine load due to power lost with the increase in engine load. There was a reduction in BTE with the increase in biodiesel percentage in the fuel blends due to the decrease in calorific value of fuel blend. EGT was found to increase with the increase in both concentrations of biodiesel in the blends and engine load. The increase in EGT with engine load is obvious from the simple fact that a higher amount of fuel was required in the engine to generate that extra power needed to take up the additional loading. In another paper titled "Performance Characteristics of a Diesel Engine Fuelled with Palm Kernel Methyl Ester and Its Blend with petroleum diesel" Igbokwe, and Obiukwu [14] examined the performance characteristics of a diesel engine fueled with palm kernel methyl ester and its blend with petroleum diesel. The produced methyl ester was blended with neat petroleum diesel at a ratio of 20% biodiesel to 80% diesel by volume and tested in a diesel engine. The test results interestingly revealed that the fuel blend (B20) produced higher torque at low and medium engine speeds than neat petroleum diesel and unblended methyl ester (B100). It was also observed that petroleum diesel developed higher torque and brake power than the unblended methyl ester (B100) at all tested speeds and showed the least brake specific fuel consumption possibly because of its higher heating value. This research aims at investigating the effect of load on the performance of CI engine using a dual fuel (palm kernel and castor biodiesels) blended with petroleum diesel in various proportions.

EXPERIMENTAL SET UP of TEST ENGINE

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The details of technical specification of diesel engine are given in Table 2

MATERIALS AND METHOD

Materials

Palm kernel oil used in this study for palm kernel methyl ester was purchased from Gboko market in Benue state, Nigeria while the castor seed oil was purchased in Lagos Nigeria. All the chemicals used in this project were purchased at Sanofan Chemical store also in Gboko.

Method

The Acid value of p.k oil was 0.7mgKOH/g. This, though is a bit above ASTM requirement for trans-esterification (≤ 0.5), many authors and researchers have successfully trans-esterified oils with 0.7mgKOH/g acid value to biodiesels. About 200ml methanol (AR) was mixed to (0.7 + 3.5 g) NaOH /litre of oil to produce sodium methoxide. The above volume of sodium methoxide was then added to the appropriate volume of oil in the reactor. The temperature was raised and maintained at 65^{o}C throughout the duration of the trans-esterification process which lasted about 70 minutes. At the end of this period, the biodiesel was allowed to settle in a 1liter separating funnel overnight or 8hrs. The mixture was noticed to have separated into two district layers. The upper light colour was biodiesel while the dark brown and thick (sometimes solid) layer at the bottom was glycerin, a byproduct in the process. Glycerin was discarded.

Acid Catalysis; Castor Oil to Diesel

Acid catalysis is a pre-treatment process to reduce the acid value of oils whose acid value is > 0.5 (ASTM requirement) before trans-esterification process. This method was applied to castor oil in this research work. Acid catalysis uses an acid (H_2S0_4) as catalyst where as trans-esterification uses a base (NaOH or KOH mostly) as catalyst in the process of biodiesel production. Castor oil had acid value of 4.5 mgKOH/g which was considerably high and had to be treated with acid catalysis to reduce it to about 0.7 mgKOH/g

Blending of Biodiesels with Petroleum Diesel

Two biodiesels; palm kernel biodiesel and castor biodiesel were blended with petroleum diesel in the following ratios: B10 (1800ml diesel, 100ml P.K, 100ml Castor), B20 (1600ml diesel, 300ml pk, 100ml castor), B30 (1400ml diesel, 400ml pk, 200ml castor), B40(1200ml diesel:500ml pk: 300ml castor), B50 (1000ml diesel: 600ml pk:400ml castor), B60(800ml diesel: 700ml pk: 500ml castor), B70 (600ml diesel: 800 ml pk:600 ml castor), B80(400ml diesel: 900ml pk: 700ml castor), B90 (200ml diesel: 100ml pk: 800ml castor). The blending was aimed at a total of 2000ml (2litres) by volume per sample.

RESULTS AND DISCUSSION

Table 1: Physical and Chemical Properties of Castor, Palm kernel Biodiesels, Petroleum Diesel

S/No	Property	Diesel	pkB100	castB100
1	Flash point	63	122	154
2	Kinematic viscosity	4.57	7.31	13.44
3	Sulfur cont	0.21	0.02	0.02
4	Specific gravity	8645	8886	9082
5	Heating val	38	29. 44	29. 67
6	Pour point	-15	-13	-18.5
7	Cloud pt.	-6.0	-21.0	-11.0
8	Cetane No			
9	Cu content	0.33	0.07	0.09
10	Iron cont	1.33	0.11	0.14

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Table 3: Technical Specification of Test Engine

S/No	Description	Specification
1	Engine Manufacturer/Model	Techequipment TD-114
2	Type	Dingle cylinder, Air-cooled, Naturally aspirated 4-stroke diesel engine.
3	Bore/Stroke	70mm/57mm
4	Compression ratio	17:1
5	maximum Torque	8.2Nm at 2700 rpm
6	Maximum brake power	2.6kw at 3600 rpm
7	Fuel injection timing	24 to 330 BTDC
8	Fuel Injection Pressure	180psi

TORQUE

It was observed (fig.1) that torque of petroleum diesel, B10, and B20 increased with load increase due to increase in combustion temperature which leads to more complete combustion during the increasing loads [8] while torque of B30, B40, B50, B60, B70, B80, B90, CastB100 and pkB100 decreased with load increase as a result of lower efficiency of combustion due to increasing viscosity and density of the higher blends which give rise to lower fuel atomization and consequently lower heat release. Torque could also have reduced as a result of lower heating value of the blends.

Torque of diesel is higher than torque of biodiesels and blends due to lower heating value of biodiesels and blends [7].

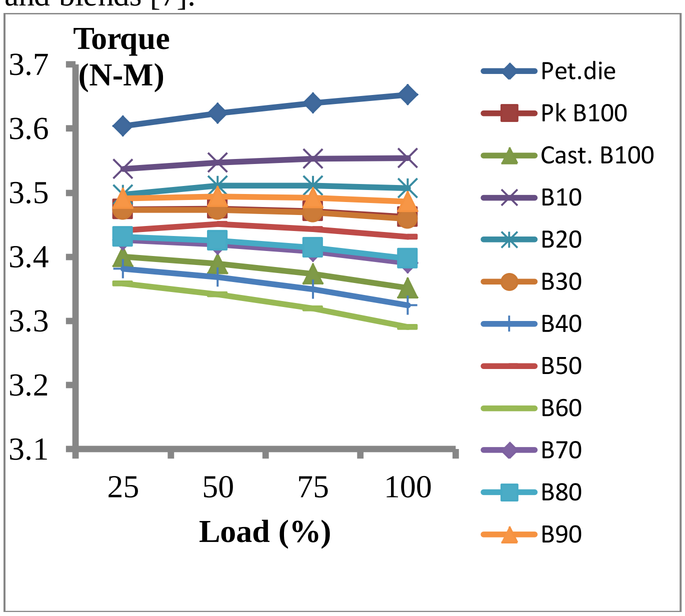

Fig 1: Effect of load variation on torque at constant speed of 2500 rpm.

BREAK POWER (B.P)

It was also observed (fig.2) that BP of diesel and B10 increased with load due to higher fuel consumption rate of the engine with increase in load [4]. It was further observed that break power decreased as biodiesel concentration in the blends increased due to lower heating value of biodiesels and blends or lower energy content of the fuel blends. The variation in break power between diesel and biodiesel blends was smaller at lower speeds than at higher speeds. At all load variations, break power of diesel was higher than biodiesel and blends due to (1) lower heating value of the biodiesels and blends and (2) higher viscosity of biodiesels and blends which adversely affects fuel atomization leading to lower combustion efficiency and lower power extraction from the fuel.

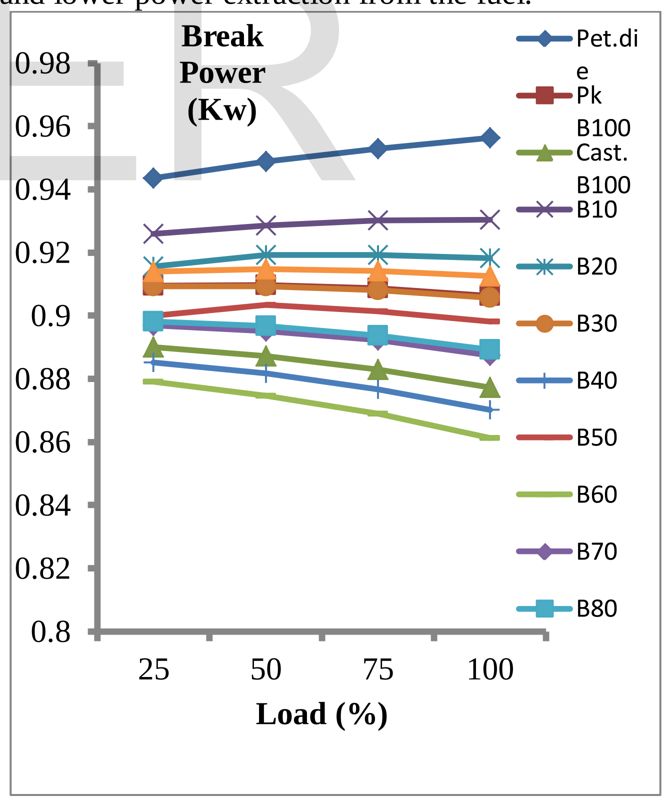

Fig 2: Effect of load variation on brake power at constant speed of 2500 rpm.

Break Specific Fuel Consumption (BSFC)

Fig. 1 shows the variation of BSFC with load at 2500 rpm constant speed. It was observed (fig. 3) that the BSFC of all samples tested increased with percentage engine load increase because the percentage increase in fuel required to obtain the necessary brake power or energy to operate the engine was higher [3]. It should be understood that higher loads need more energy from the engine to overcome and this energy is gotten from increased fuel supply, hence rising BSFC. It was further observed that BSFC increased with biodiesel concentration in the blends due to lower calorific value [2]

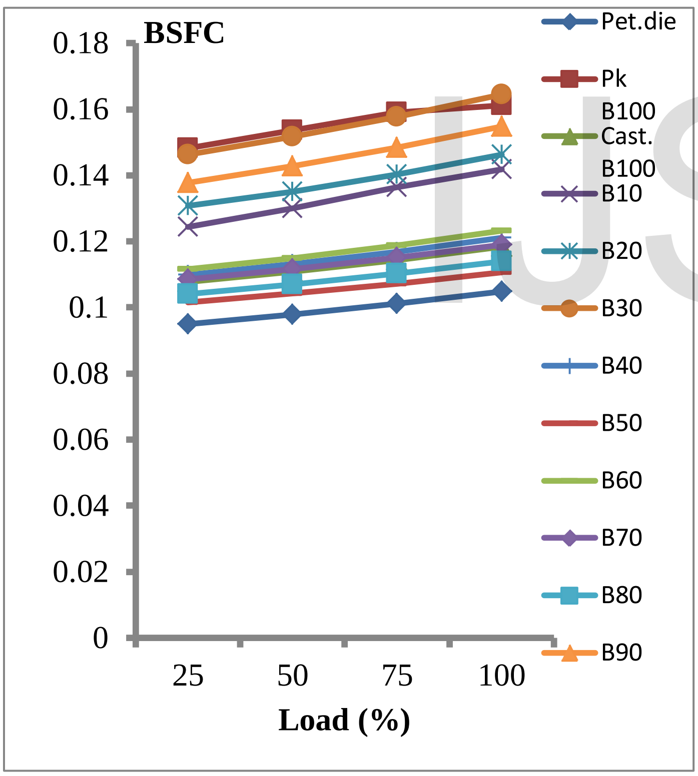

Fig 3: Effect of load variation on brake specific fuel consumption (BSFC) at constant speed of 2500 rpm.

Break Specific Energy Consumption (BSEC)

It was observed (fig. 4) that the BSEC of all samples tested increased with percentage engine load increase at all speeds of test because the percentage increase in fuel required for operating the engine was higher than the percentage increase in engine brake power due to relatively higher portion of the heat losses at higher loads [3]. It was further observed that BSEC decreased with biodiesel concentration in the blends due to lower calorific value as blends increased in the blends [2].

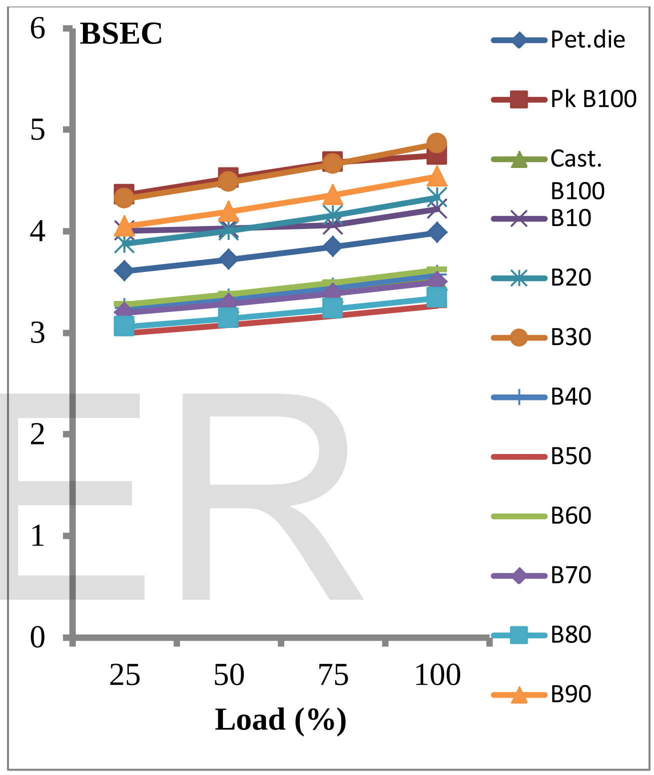

Fig 4: Effect of load variation on brake specific energy consumption (BSEC) at constant speed of 2500 rpm.

Break Thermal Efficiency (BTE)

It was also observed (fig 5) that break thermal efficiency decreased with load increase due to increase in losses and decrease in break power with load or increase in fuel consumption [2]. At 2500 rpm, BTE of diesel was greater than pkB100, B10, B20, B30 and B90 because of its higher calorific value and lower viscosity [11]. Petroleum diesel however was lower in BTE than B60, B80, B40, B50, B70 and cast B100 probably because of additional lubricity provided by the fuel blends which reduced friction and, therefore, the amount of energy that would have gone into overcoming it. As biodiesel increased in blends BTE increased up to B40 due to increase in combustion temperature as blends contain more oxygen. So, higher combustion temperature resulted in higher combustion efficiency which increased BTE. BTE decreased with further addition of biodiesel from B50 to B90 due to lower calorific value and higher density (ISRN, 2011).

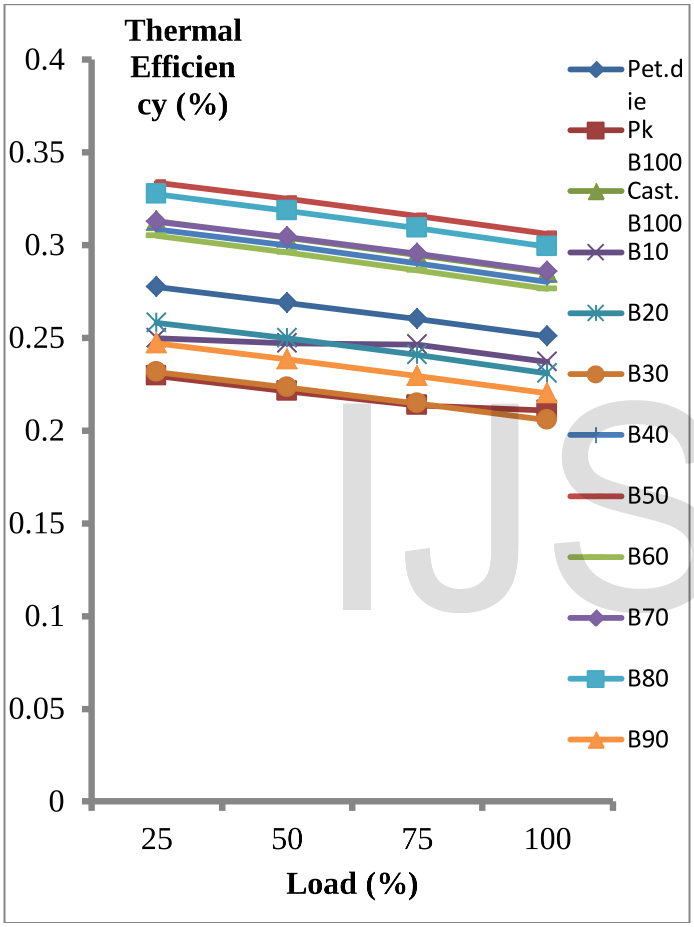

Fig 5: Effect of load variation on thermal efficiency at constant speed of 2500 rpm.

Exhaust Gas Temperature (EGT)
Fig. 6 shows that for all samples tested at the engine speed, EGT increased with load increase because higher amount of fuel was needed to generate extra power needed to take up additional loads [10]. It was also observed that two patterns described the behavior of EGT with biodiesel concentration. From B10 to B40, EGT increased as biodiesel concentration in blends increased due probably to better combustion and overall increase in operating temperature. At B50 where total biodiesel in blend equals diesel in the blend, EGT decreased. Between B60 to B90, EGT decreased as biodiesel further dominated the blends due to increased oxygen content of the blend with biodiesel increasing it [17]. At the speed considered B60, B40, castB100, B70, B80, and B50 produced higher exhaust gas temperature than diesel due to high viscosity and density of biodiesel and blends. This gave rise to higher mass flow rate per unit volume of fuel which may have resulted to the release of more energy during combustion and, therefore, higher exhaust temperatures.

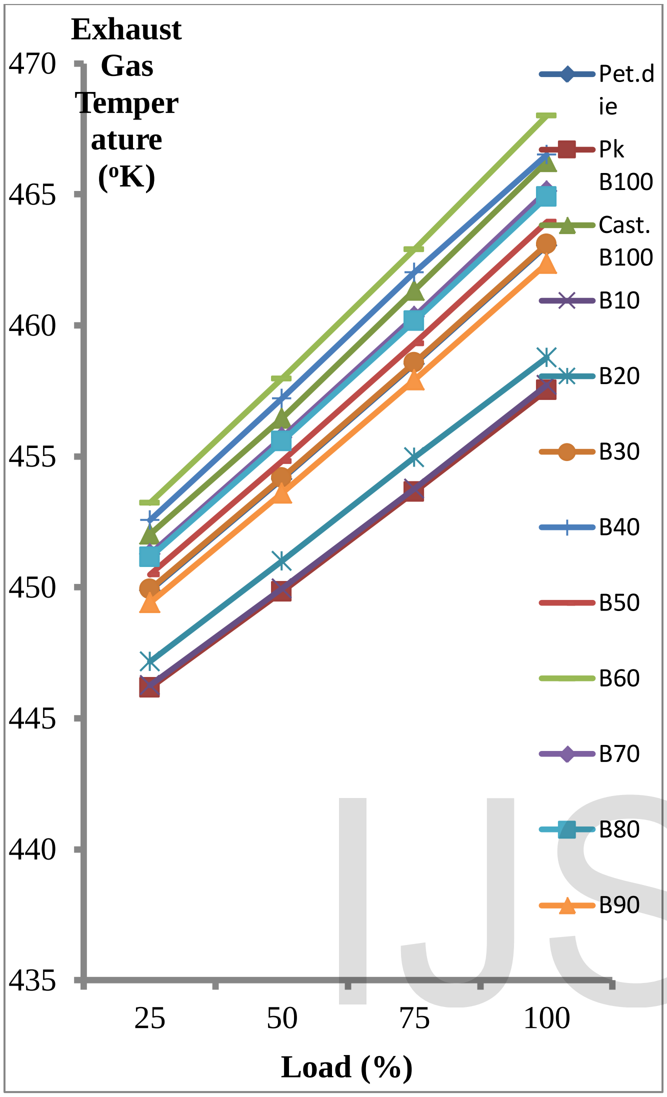

Fig 6: Effect of load variation on exhaust gas temperature at constant speed of 2500 rpm.

EMISSIONS

H/C

From Fig.7, it was observed that H/C emissions of B10, B20, B90 and pkB100 increased with load while the H/C emissions of B30, B60, B50, B40, castB100, B80 and B70 decreased as load increased due to oxygen content of biodiesel and blends, which is the main reason for better combustion and reduction in H/C emissions. Also increased combustion temperatures associated with high engine loads could be accountable for the decreasing H/C with increasing loads [20].

It was further observed at the test speed that H/C emissions of all samples decreased as biodiesel concentration in the blends increased up to B40 due to increased oxygen content of blends. H/C emission of samples was observed to increase with further biodiesel concentration at B50 where total biodiesel equals total diesel in the blends. Further increase in biodiesel concentration in the blends also increased the H/C emissions of biodiesel and blends.

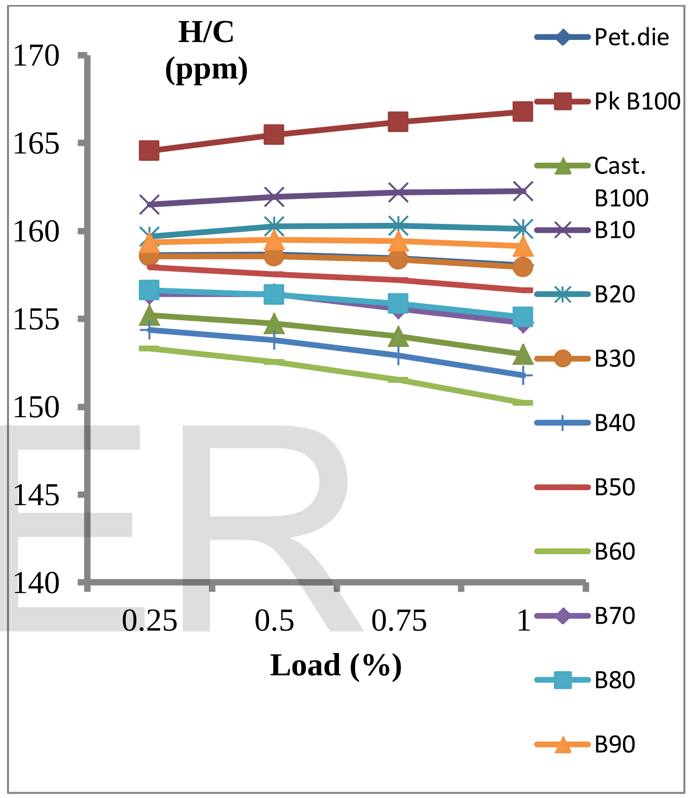

Fig7: Effect of Load variation on H/C emissions of test samples at 2500 rpm

NOx

Fig.8 shows that at 2500rpm, NOx emissions of pkB100, B10, B20 increased with loads due to higher combustion temperatures arising from improved combustion, while for the rest of the other samples, NOx decreased as load. At the constant speed of 2500 rpm, PkB100, B10, B20 and B90 produced more NOx than petroleum diesel while B30 produced same NOx with petroleum diesel. Petroleum diesel, in turn, produced more

NOx emissions than B50, B70, B80, castB100, B40 and B60 respectively. NOx emissions were also observed to increase with content of biodiesel in the blends.

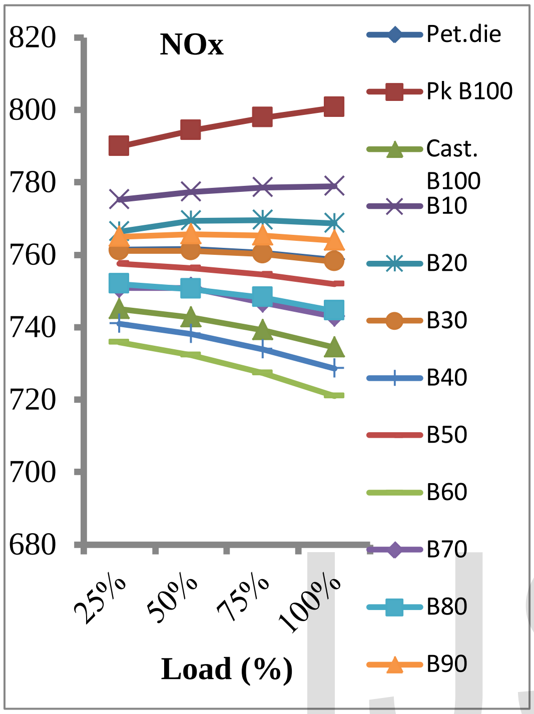

Fig 8: Effect of Load variation on NOx emissions of test samples at 2500 rpm

CO

At 2500 rpm (Fig.9), CO emission of diesel, castB100, B30, B40, B50, B60, B70 and B80 decreased as engine loads increased due to increased combustion temperature associated with higher engine loads. CO emission of PkB100 increased with load due to the fact that as the load is increased, the fuel consumption is also proportionally increased. Due to insufficient air in the combustion chamber, there may be incomplete combustion of fuel and hence increased CO [10] while B10, B20, and B90 did not show any significant change with load increase.

It was further observed at the engine speed of test that CO emissions decreased as biodiesel concentration in the blends increased up to B40 due to oxygen content of blends which supports complete combustion thereby reducing CO emissions. From B50 to B90, **CO** emissions increased again due to incomplete combustion as a result of higher viscosity of blends which gives rise to lower fuel atomization and subsequently lower combustion efficiency.

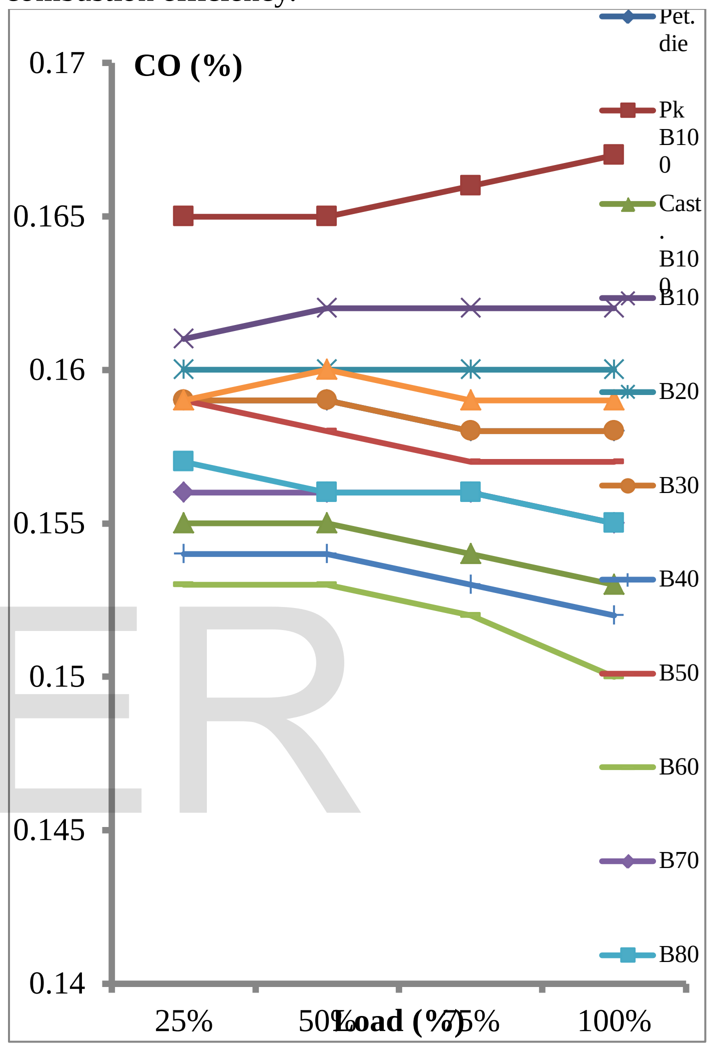

Fig 9: Effect of Load variation on CO emissions of test samples at 2500 rpm

SMOKE OPACITY

The smoke opacity (Fig.10) of petroleum diesel, cast B100, B30, B40, B50, B60, B70 and B80 decreased with loads increase while pkB100, B10, B20 and B90 increased with load increase due to high density and viscosity of biodiesels and blends. The higher viscosity and density of pure biodiesel deteriorate the fuel atomization and increase exhaust smoke. Smoke opacity decreased with biodiesel concentration up to B60 due to oxygen molecule in biodiesels and blends structure. It rose again from B60 to B90 with further biodiesel concentration in blends due to incomplete combustion of the samples as a result of the high viscosity and density of blends.

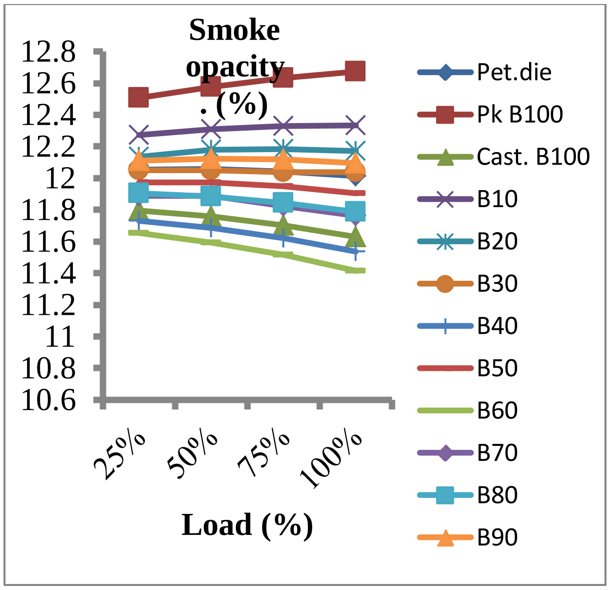

Fig 10: Effect of Load variation on Smoke Opacity of test samples at 2500 rpm

CONCLUSION

1. At the constant speed of test, torque increased with increase in load for petroleum diesel (B0), B10 and B20 while it decreases with load for the remaining samples.
2. Break power decreased with increase in load for all fuel samples except for petroleum diesel for which it increased with load.
3. The BSFC and BSEC increased as load increased for all the fuel samples tested. However, petroleum diesel (B0) consistently had less BSFC and BSEC than the biodiesels and their blends with petroleum diesels.
4. Generally, break thermal efficiency (BTE) decreased with increased load for all fuel samples tested. The BTE and BSEC of petroleum diesel (B0) was lower than that of B40, B50, B60, B70, B80, CAST100 and higher than pkB100, B10, B20, B30 and B90.
5. Generally, emissions (H/C, CO, NOx, smoke opacity) decreased with increased load for all the fuel samples except for pk100 for which all the emissions increased with increase in speed

From the analysis above, it can be concluded that petroleum diesel (B0), B10, B20 and B30 are similar in performance and performed better averagely than others. They can, thus, be recommended for use in CI engines.

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