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Parametric Study of Jatropha Blended Gasoline Fuel In Compression Ignition Engine Of A Small Capacity Diesel Engine

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ABSTRACT : *In this study, Jatropha Biodiesel was tested in a single cylinder direct-injection diesel engine to investigate the operational parameters of a small capacity diesel engine under six engine loads. Here the jatropha oil is used as a non edible oil to produce the biodiesel. The investigated blends were 40/60%, 30/70%, 20/80% and 100% jatropha biodiesel at various loads. The jatropha biodiesel was obtained from National Research Institute for Chemical Technology Zaria-Nigeria and was within EN, BIS and Brazil specifications for biodiesel. Each blend was tested on a short term basis of three hours. The result shows that the brake thermal efficiency increased for all tested blends at lower engine loads and decreases at higher engine loads. The specific fuel consumption (S.F.C) increased for lower blends compared to neat jatropha oil while higher engine powers were obtained for lower blends compared to neat jatropha oil. In all the investigated operational parameters, the diesel reference fuel had better performance to jatropha biodiesel blends except in the percentage heat loss to the exhaust where jatropha biodiesel blends had better performance.*

KEYWORDS: *Jatropha, Biodiesel, Brake Power, Brake Thermal Efficiency, Specific Fuel Consumption.*

I. INTRODUCTION

The enormous amount of energy being consumed across the world is having adverse effect on the ecosystem of the planet. The technologies for fossil fuels extraction, processing, transportation and their combustion have environmental concerns (Munear, 2005). With dramatic growth in the use of compression ignition engines in recent years for transportation, power generation, agriculture, earth moving machines and several industries due to its inherent fuel economy, ease in operation, maintenance and long life.The demand for conventional petroleum fuels and environmental degradation resulting from diesel combustion can no longer be ignored (Naveen Kumer, 2005).To provide long lasting solution to these twin problem, the use of alternative fuels have been effectively utilized for partial or complete substitution of conventional petroleum fuels in compression ignition engines.Non edible vegetable oils have demonstrated potentials as alternative fuels which could be use in existing diesel engines without any major engine hardware modifications at a relatively low price (). Some positive attributes exhibited by the oils include; biodegradable, higher heat content, liquid nature-portability, lower aromatic content and lower sulphur content.

Jatropha curcas (Linaeus), a non edible oil bearing and drought hardy shrub with ecological advantages is found to be the most appreciated renewable alternative source of bio-diesel (Tint et al, 2009). Vegetable oil in neat form is not suitable for diesel engine due to its high viscosity. The commonly employed methods of reducing the viscosity of vegetable oils are blending with diesel, emulsification, pyrolysis, cracking and transesterification. The transesterification method of vegetable oils to mono alkyl esters (biodiesel) appears to be the best route amongst all these methods (Xie, 2006).Several researchers have prepared blends of varying proportions of jatropha curcas oil and diesel and compared the performance with diesel fuel in compression ignition engines. Relatively high viscosity, lower volatility and reactivity of unsaturated hydrocarbon chains of these oils cause problems of high emissions and low break thermal efficiency (Vellgulh, 1983). Straight vegetable oils are too vicious and create difficulties over prolonged use in the diesel injection diesel engines (Ziejewski, 1984).

Many researchers observed that bio-diesel containing 10-12% oxygen on weight basis causes reductions in engine torque and power due to its lower energy content. However, some studies have also reported that bio-diesel can cause a slightly higher engine power than conventional diesel fuel. This is because of complete combustion with the fuel oxygen in the fuel rich flame zone. The complete combustion also reduces exhaust emission such as hydrocarbons, smoke and carbon monoxide (Usta et al., 2005).The aim of the study is to determine the operational parameters of a biodiesel fuel compression ignition engine test for blends of 60/40%, 70/30%, 80/20% and 100/00% for jatropha bio-diesel fuel.

II. MATERIALS AND METHODS

The Engine Test bed : A Petter AA1, TD114 diesel engine was used for the test. It is a single cylinder, two stroke, horizontal type unit with a cylinder bore of 70mm, piston stroke of 57mm and a compression ratio of 17:1. It has maximum torque of 8.2Nm at 3600rpm, maximum brake power of 2.6kW at 3600rpm, fuel injection timing of 24° to 33° BTDC. The engine unit was connected with other appropriate accessories (instrumental unit).

Experimentation : The experiment aims at determining the operational parameters of a compression ignition engine run on jatropha biodiesel. Thus, the Petter AA1, TD114 diesel engine was operated as an Automobile engine. Each of the blends consisted of six test runs that lasted for three hours since the engine is a small capacity- laboratory base. The engine speed and torque were operated manually and the following parameters measured; engine temperature, fuel consumption, exhaust temperature and developed power. The engine was first run on the reference diesel fuel and consequently on the blends of jatropha biodiesel after which the engine was serviced and replaced with new lubrication oil and fuel system flushed with the next test fuel blends. The jatropha oil was obtained from National Research Institute for Chemical Technology, Zaria Kaduna State Nigeria (NARICT).

Methods : The operational parameters of the engine were evaluated from Equations 1 to 9 (Eastop, 1993)

(a) Power Developed.

The power developed in an engine is given by:

$$P=\frac{2\Pi NT}{60} \quad \ldots\ldots\ldots 1$$

Where N is the number of revolutions per minute and T is torque.

(b) Measurement of Air consumption

The expression for air consumption in kg/hr is given by:

$$M_a = 2.98\sqrt{\frac{P}{T}hmm} \quad \text{Kg/hr} \ldots\ldots\ldots 2$$

Where P is measure in millibar and T in °K

(c) Measurement of fuel consumption

The fuel consumption is determined by measuring the time (t) taken for an engine to consume a given a volume of fuel:

$$M_f = \frac{28.8 \times S_{gf}}{t} \quad \text{kg/hr} \ldots\ldots\ldots 3$$

Where: S_{gf} is the specific gravity of the fuel.

t, time taken to consume a given quantity of fuel.

(d) Specific fuel consumption

This is defined as the fuel consumption rate divided by brake power:

$$\text{S.f.c} = \frac{M_f}{P_B} \times 10^3 \quad \text{(g/kwh)} \ldots\ldots\ldots 4$$

(e) Brake Thermal Efficiency.

The maximum overall efficiency of energy conversion is expressed as the brake thermal efficiency given as:

$$\eta_b = \frac{P_B}{M_f \times H} \times 3600 \quad \ldots\ldots\ldots\ldots\ldots\ldots 5$$

Where P_B is measured in kW and M_f is measured in kg/hr.

(f) Percentage heat Loss in Exhaust
The heat carried away by the exhaust gases expressed as a percentage of the heat input is:

$$\text{Percentage heat loss in exhaust} = \frac{(M_a \times M_f) \times C_p \times \Delta t \times 100}{M_f \times H} \quad \ldots\ldots\ldots 6$$

Where: H is the calorific value of the fuel measured in kJ/kg
Δt Is the difference between exhaust and ambient temperatures
C_p Is the specific heat of exhaust gases.

(g) Volumetric Efficiency
For this study, the volumetric efficiency is given as:

$$\eta_v = \frac{M_a}{60\,N} \times \frac{1}{V_s\,\rho_a} \quad \text{for a two stroke engine} \quad \ldots\ldots\ldots 7$$

Where M_a is in kg/hr,
V_s = Swept volume
ρ_a = Density of air

(h) Correction of Brake Power to Standard Atmospheric Pressure and Temperature.
The most significant correction is made to brake power:

$$P_B(corrected) = P_B(measured) \times \frac{749\ mmHg}{P_O} \times \frac{273 + t_o}{273 + t_s} \quad \ldots\ldots\ldots 8$$

Where t_s is the standard condition and t_o is the observed condition.

(i) Measurement of Air/Fuel ratio
It is given by:

$$A / F = \frac{m_a}{m_f} \quad \ldots\ldots\ldots\ldots\ldots\ldots 9$$

(j) Measurement of Exhaust Temperature
Exhaust temperature was measured by a chrome/Alumel thermocouple conforming to BS1827.

(k) Measurement of Torque
The hydraulic dynamometer measures the engine torque and displays it on the torque meter located on the instrumentation unit.

(l) Measurement of speed
Engine speed was measured electrically by a pulse counting system.

III. ENGINE PARAMETERS

Tables 1, 2 and 3 shows diesel engine test parameters, properties of biodiesel jatropha obtained from NARICT and properties of diesel and Jatropha biodiesel blends.

Table 1: Specification of Diesel Engine Test Bed

S/No	Parameters	Value
1	Ambient Temp	32° C
2	Engine Bore	70mm
3	Engine Stroke	57mm
4	H_2	35.8mm of water
5	Density of Air	1.1548kg/m^3
6	Quantity of fuel consumed	8ml
7	Swept volume	$2.19\times 10^{-4} m^3$

Table 2: Properties of Biodiesel Jatropha obtained from NARICT

S/No	Fuel properties	ASTM P_s 975 diesel	ASTM 121 Biodiesel	Biodiesel Jatropha obtained from NARICT	Unit
1	Aniline point	_	_	27	^{0}C
2	Specific gravity at 60^{0}F	0.85	0.88	0.88	
3	API gravity	_	_	29.1	
4	Carbon Residue	<0.35	0.05	1.21	Wt%
5	Kinematic viscosity at 40^{0}C	1.3-4.1	1.90-6.0	5.82	Cst
6	Colour			>1.0	
7	Diesel index			23.5	
8	Calorific value	45	41	44	KJ/Kg
9	Flash point	60-80^{0}C	-100 to 170^{0}C	133	^{0}C
10	Cloud point	-5 to 5^{0}C	-3 to 12^{0}C	-3	^{0}C

(Source: NARICT)

Table 3: Properties of Diesel, Biodiesel Jatropha

Fuel blend	**Specific gravity**	**Calorific value (KJ/kg)**
Diesel	0.8400	39000
B60	0.8530	41139
B70	0.8553	41090
B80	0.8576	40174
B100	0.8621	39174

IV. RESULTS

Tables 4 – 10 show the summaries for analyzed results in comparison with the reference diesel fuel. The parameters analyzed are the thermal efficiency, specific fuel consumption, power, percentage heat loss, exhaust gas temperature, volumetric efficiency and the air-fuel ratio for the diesel and the biodiesel blends.

Table 4: Brake Thermal Efficiency for the Tested Blends (%)

S/No	**Torque (Nm)**	**Diesel**	**B60**	**B70**	**B80**	**B100**
1	0.5	5.37	1.28	3.54	3.35	3.69
2	2.2	17.99	5.48	9.13	11.05	11.50
3	3.3	18.86	9.63	9.28	9.40	10.75
4	4.6	22.28	10.77	9.93	10.43	11.40
5	5.4	20.00	11.40	9.17	10.76	11.33
6	5.8	18.29	10.62	9.38	12.06	12.23

Table 5: Specific fuel consumption (s.f.c) for the Tested Blends (g/kwh)

S/No	Torque (Nm)	Diesel	B60	B70	B80	B100
1	0.5	1718.84	2660.30	2469.30	2673.94	2489.76
2	2.2	513.10	861.79	959.14	810.28	799.03
3	3.3	489.30	908.01	943.39	952.79	780.05
4	4.6	404.42	812.39	881.50	859.06	805.18
5	5.4	461.11	766.94	954.97	832.12	810.91
6	5.8	404.57	823.56	933.47	742.99	750.93

Table 6: Percentage heat loss to exhaust for the tested blends (%)

S/No	Torque (Nm)	Diesel	B60	B70	B80	B100
1	0.5	29.16	9.74	10.67	10.12	16.54
2	2.2	29.21	8.30	8.41	9.18	15.55
3	3.3	23.20	6.57	6.57	6.23	11.98
4	4.6	21.90	6.77	6.19	6.46	11.86
5	5.4	17.58	6.72	5.18	6.49	10.92
6	5.8	17.89	5.40	4.47	6.65	10.86

Table 7: Table 6 Power Developed for the Tested Blends (W)

S/No	Torque (Nm)	Diesel	B60	B70	B80	B100
1	0.5	116.83	116.69	116.82	116.82	116.82
2	2.2	514.06	499.32	499.32	495.65	495.65
3	3.3	757.29	743.32	743.32	737.66	723.56
4	4.6	1036.43	830.82	824.44	818.15	792.73
5	5.4	1194.15	911.22	893.60	876.24	841.18
6	5.8	1272.93	1033.39	1001.35	981.35	941.27

Table 8: Exhaust gas temperature for the tested blends (°C)

S/No	Torque (Nm)	Diesel	B60	B70	B80	B100
1	0.5	134	97	97	96	125
2	2.2	168	110	118	108	153
3	3.3	197	128	130	122	181
4	4.6	201	132	134	127	186
5	5.4	212	134	136	131	187
6	5.8	247	137	138	134	195

Table 9: Air/Fuel ratio for the tested blends

S/No	Torque (Nm)	Diesel	B60	B70	B80	B100
1	0.5	110.51	60.69	66.49	62.57	68.71
2	2.2	82.77	42.80	39.18	47.53	49.35
3	3.3	57.39	27.17	26.55	26.83	30.50
4	4.6	49.54	26.88	23.95	26.49	29.17
5	5.4	37.09	26.11	19.49	25.34	26.60
6	5.8	31.46	20.15	16.33	25.22	25.11

Table 10: Volumetric Efficiency for the tested blends (%)

S/No	Torque (Nm)	Diesel	B60	B70	B80	B100
1	0.5	61.79	52.51	53.40	54.42	55.64
2	2.2	60.79	53.37	53.78	55.13	56.44
3	3.3	60.29	54.58	55.41	56.55	57.66
4	4.6	59.96	53.99	51.56	56.27	58.07
5	5.4	60.00	54.47	50.86	57.62	58.94
6	5.8	59.99	51.84	47.61	58.52	58.90

V. DISCUSSION OF RESULTS

Brake Thermal Efficiency : Diesel, the reference fuel shows a decreasing trend of brake thermal efficiency as exhibited in figure 1 with increase in engine speed. Generally, there is consistent decrease in the brake thermal efficiency with the addition of jatropha oil in biodiesel jatropha blends. The decreasing trend shows no significant difference between higher and lower jatropha oil/diesel fuel blends. This work is contrast with the earlier work of (Nwafor, 2004) who reported higher brake thermal efficiency as compared to diesel. The maximum brake thermal efficiency has been observed with B100 with a value of 12.23%.

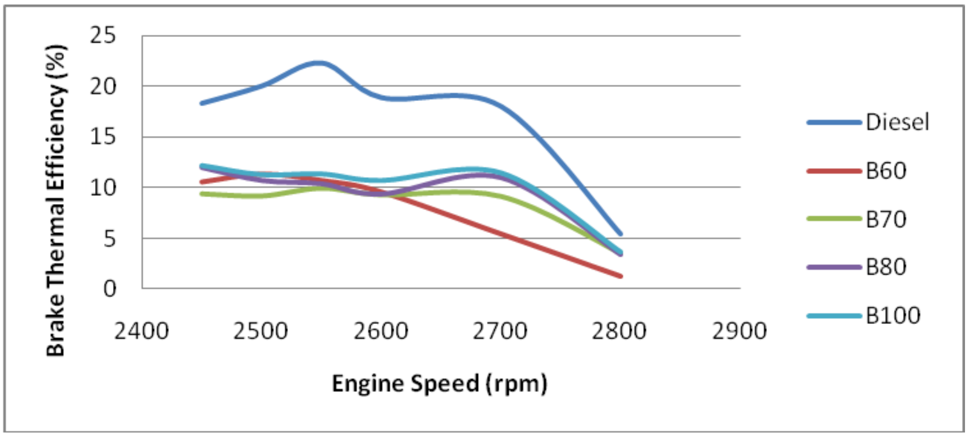

Figure 1: Variation of Brake Thermal Efficiency with Engine Speed for Diesel and all Tested Blends

Spcific Fuel Consumption : Generally, the engine clearly exhibit more fuel consumption pattern as the engine speed increases with higher blends having more rate of fuel consumption. For the biodiesel jatropha, B100 exhibited the lowest specific fuel consumption at all speeds and load conditions. This signifies that lower engine speeds are required for fuel economy. This is in confirmative to the work of (Nwafor, 2004).

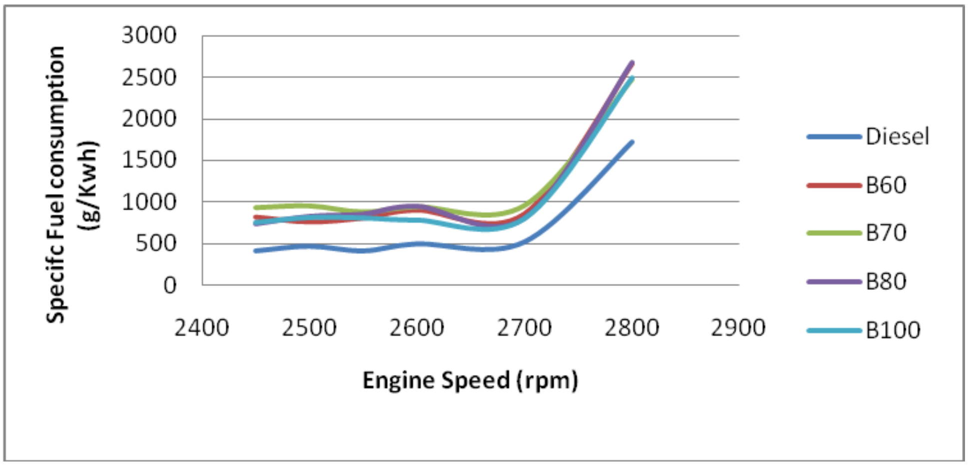

Figure 2: Variation of Specific Fuel Consumption with Engine Speed for Diesel and all Tested Blends

Brake Power : Higher powers were obtained at lower engine speeds for diesel and jatropha biodiesel blends. There were decreases in the brake power as engine speed increases for increased percentage substitution of jatropha oil. The optimum brake power for the jatropha biodiesel blends were for B60 while B100 exhibited the minimum brake power. The diesel referenced fuel clearly demonstrated superior characteristics of power output available for work. This conforms to the work of (Neto da Silva, 2003) in which they observed that 5% of biodiesel and diesel resulted in increase in torque and power output while 30% blends gave a reduction in torque and power output. The works of Gideon and Wara (2012) also ascertain to that.

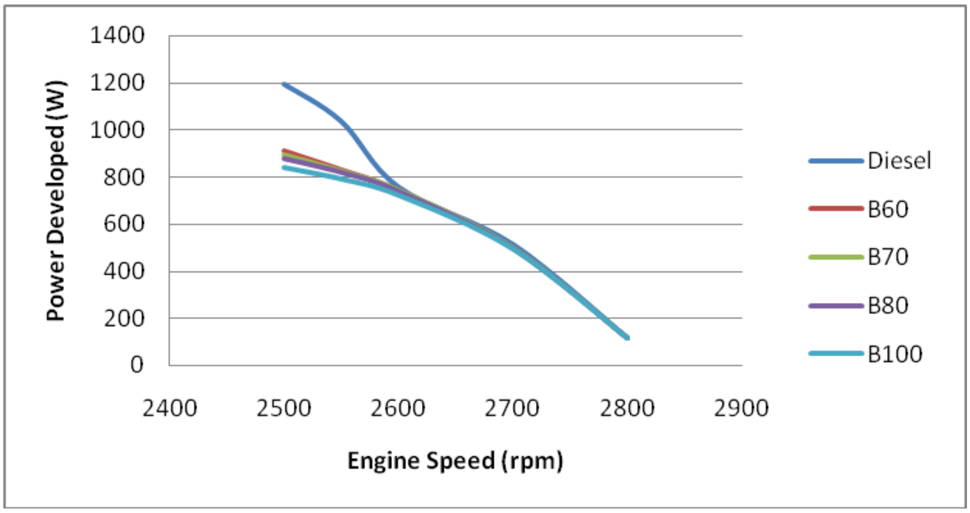

Figure 3: Variation of Brake Power with Engine Speed for Diesel and all Tested Blends

Exhaust Gas Temperature : The biodiesel jatropha blends exhibited good characteristics in exhaust gas temperature as it reduces for increased in the engine speed. This characteristic is healthy as less useful heat energy is lost through the gases. In comparison to diesel reference fuel, the experimental result showed that exhaust gas temperature were lower for biodiesel jatropha blends in comparison to diesel with B80 having the optimum result. This is in confirmative to the earlier work of Gideon and Wara (2012). However, this is contrast to the work of (Usta et al., 2005) which they reported that blends of biodiesel demonstrated higher exhaust temperatures than that of diesel reference fuel.

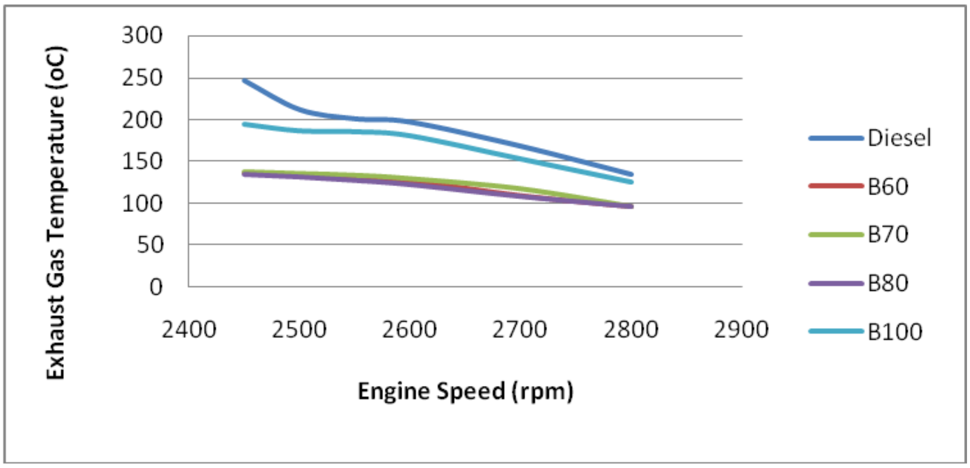

Figure 4: Variation of Exhaust Temperature against Engine Speed for Diesel and all Tested Blends

Percentages heat loss to Exhaust : The percentage heat loss shows a reduction with increasing engine speed as noted in the exhaust gas temperature for both diesel and jatropha oil/diesel blends. For higher biodiesel jatropha blends, there were significant reductions in the percentage heat losses with B80 having the minimum. It is noted that the biodiesel jatropha fuel blends lost less useful heat energy when compared to diesel reference fuel. This useful heat is lost through the flue gases leaving.

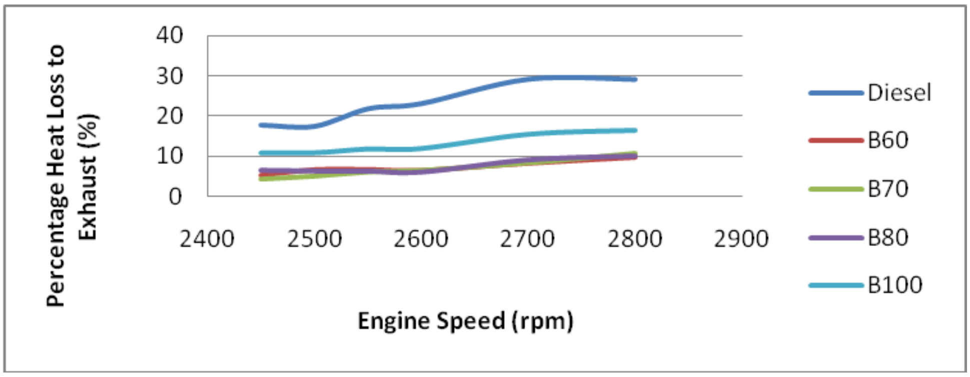

Figure 5: Variation of Percentage Heat Loss against Engine Speed for Diesel and all Tested Blends

Air / Fuel Ratio : The air /fuel ratio values increases at higher engine speeds for diesel reference fuel and other biodiesel jatropha blends with diesel having higher values. The maximum air / fuel ratio value observed for biodiesel jatropha blends was for B100. There were increased in engine noise for higher biodiesel jatropha blends and this could be attributed to the deficient air/fuel ratio.

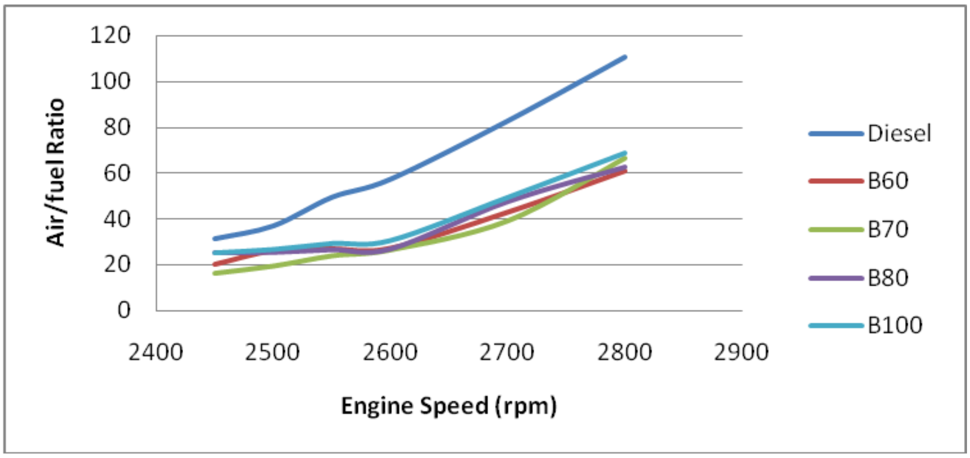

Figure 6: Variation of Air/Fuel ratio against Engine Speed for Diesel and all Tested Blends

Volumetric Efficiency : There were no significant difference in the volumetric efficiencies at lower and higher speeds for diesel reference fuel and biodiesel jatropha blends. However, the diesel reference demonstrated better volumetric efficiency at all speeds with B100 having the best among the biodiesel jatropha blends.

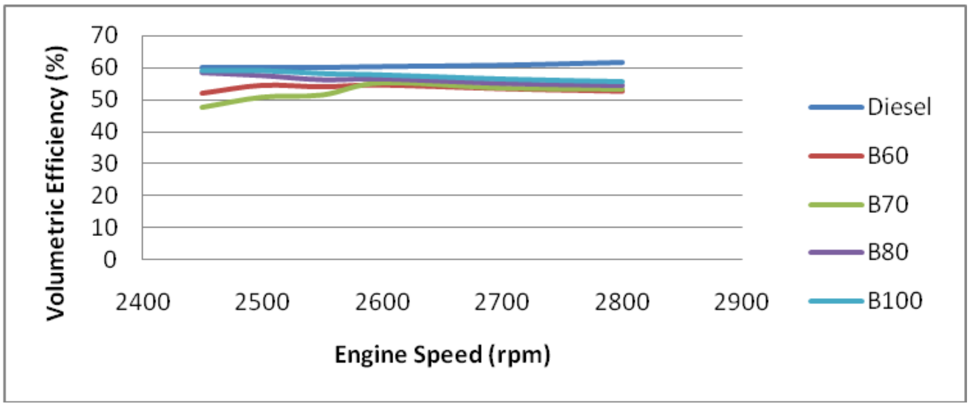

Figure 7: Variation of Volumetric Efficiency against Engine Speed for Diesel and all Tested Blends

VI. CONCLUSION

The operational parameters of a single cylinder two stroke engine run on biodiesel jatropha as an automobile engine were determined. The study shows that diesel reference fuel exhibited superior performance characteristics when compared to biodiesel jatropha blends in terms of brake power, specific fuel consumption, brake thermal efficiency, air/fuel ratio and volumetric efficiency while biodiesel jatropha blends demonstrated better performance for exhaust gas temperatures and percentage heat loss to exhaust. Furthermore, for the biodiesel jatropha blends, B100 gave best optimum result due to its relatively high brake thermal efficiency and low specific fuel consumption despite its high percentage of heat loss to flue gases.There was no reaction of the biodiesel jatropha blends with engine parts as there was no engine starting problems, wear out of components or breakdown. No long term assessment, emission characteristics or endurance tests including breakdown of biodiesel jatropha were carried out.

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