American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-7, Issue-1, pp-288-297
www.ajer.org
Research Paper Open Access

An Analytical Performance Investigation of A Spark-Ignition Automobile Engine While Using Ethanol Blends As Fuel.

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ABSTRACT: Spark-ignition internal combustion engines, used as prime movers for most passenger cars are conventionally powered by a fossil fuel commonly known as petrol or premium motor spirit (PMS).However, recent global interest in reducing the negative environmental impact caused by the harmful pollutants emitted due to its hydrocarbon nature and the gradual depletion of crude oil reserves has generated renewed worldwide interest in the search for alternative fuels for powering automobiles. This paper attempts to examine the feasibility of using ethanol that is blended with this conventional fuel in a variety of ratios as an alternative through an evaluation of some of the key performance parameters of a typical automobile engine. The investigated spark ignition engine was assumed to be operated and regulated from the lowest to the maximum operating speed while observing the fuel flow rate. At the design nominal speed, the rate of flow rate for the unblended 100% ethanol was found to be about 50% higher than that of its conventional counterpart of pure PMS. Furthermore, the comparative analysis revealed that a 100% unblended ethanol attracts a very little percentage of thermal efficiency that is higher than when using unblended PMS. It concludes that in addition to its well known environmental friendly advantages, pure ethanol when blended with the normal fossil fuel can effectively serve as a reliable alternative for powering the cars on our highways.

Keywords: Ethanol, Fuel flow, Engine speed, Indicated, Brake, Thermal efficiency

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Date of Submission: 15-01-2018 Date of acceptance: 29-01-2018

I. INTRODUCTION

An automobile is a self- propelled passenger vehicle that usually has four wheels and an internal combustion engine (ICE) used for land transport [1]. The ICE converts the chemical energy of the fuel used into mechanical energy utilized for the running of the automobile. The significance of the automobile for land transportation cannot be over-stressed as its lack is an indication of the poverty level of any country [2]. Movement of goods and people from one place to another is very critical in maintaining communication between nations.ICEs are powered by conventional fossil fuels such as gasoline, diesel and gas. However, there is a world-wide concern about the impact of these fuels on the environment due to the tail pipe emissions generated by them. The rising cost and depletion of fuel reserves plus frequent inconsistent supply of the commodity along with the growing ownership price of automobiles for the average Nigerian are factors that have prompted the Federal Government of Nigeria (FGN) to seek alternative, renewable and environmentally friendly fuels as a substitute for conventional gasoline used in our road transport sector. Gasoline is popularly known as Premium Motor Spirit (PMS) and in pursuance of the E10 policy which mandates the blending and use of 10% ethanol and 90% PMS as the fuel for running our vehicles [3], hence this research paper is a contribution to ensure its full realization.The Ethanol used as fuel (ethyl alcohol) is the same type of alcohol found in alcoholic beverages [4]. It is 98% pollution free, biodegradable, renewable and leaves no carbon when combusted in engines [5]. Nigeria is blessed with abundant raw materials for the production of ethanol which includes sugar cane, cassava, sorghum, Nipa palm, maize and sweet potatoes [6]The use of Ethanol in Spark Ignition (SI) Engines dates back to the days of Henry Ford, Samuel Morey and Nicholas Otto who designed engines to run on ethanol between 1824 and 1860. The performance of such engines has been found to be directly influenced by the physicochemical properties of ethanol [7]. These properties influence not only the engine performance but also affect the emissions characteristics. The most attractive properties of ethanol as a potential fuel for powering SI engines include the octane number, flame speed and latent heat of vaporization when compared to PMS [8]. In a related work gasoline has been revealed to have higher a octane number than

PMS hence better antiknock properties allowing for increased engine compression ratio thereby increasing engine efficiency [9]. Its self-ignition temperature and flash point have been discovered to be higher than those of gasoline making it safer to be transported and stored. In order to effectively use a higher blend of ethanol-PMS, a modification of the engine may be required in order to minimize the corrosive tendencies associated with the ethanol component of the fuel on some of the engine's mechanical parts [9]. It has further been revealed that the lower calorific value (LCV) of ethanol is about one-third less than that of PMS and hence the tendency for higher fuel consumption (up to one third) may be experienced when using ethanol [10].

Several researchers have reported on the effect of PMS-ethanol blends in a variety of ratios by investigating the performance and emissions of SI engines. Shane et al [11] experimented on an SI engine originally designed to run on PMS by using 10% and 20% ethanol blends. It was deduced that ethanol blend can be used in the engine without any negative draw back with the fuel conversion efficiency remaining the same but with great reduction in carbon monoxide (CO) emissions. They however observed that a 20% blended decreased the fuel conversion efficiency and brake power with a further reduction in CO emissions. Similarly, the effect of lower ethanol gasoline blends of up to 20% by volume on the performance of a single cylinder four-stroke SI engine was carried out at a wide-open throttle and variable engine speed between 4000-8000rpm in which the result compared favorably with PMS as the baseline fuel [7]. It revealed that with an increase in the ethanol content, the power, torque, fuel consumption, brake mean effective pressure and carbon dioxide (CO_2) emission of the engine increased while those of hydrocarbons (HC) and CO decreased.

By varying the rotational speed of a four-stroke SI engine, Jitendra et al [11] experimented with blends of 5%, 10%, 15% and 20% and evaluated its performance characteristics along with the exhaust emissions. A reduction in exhaust gas emissions with an increase in brake thermal efficiency was observed during which the 10% blend was concluded to be the most effective despite the slight increase in pressure. A further research was conducted by Farha et al [12] to estimate the performance and pollutant emissions of a single cylinder four-stroke SI engine using ethanol blends in steps of 20% up to 80% while varying the compression ratio between 8.1 and 10.1 and at different power settings. The results of previous research as shown above reveal that the powering of spark-ignition ICEs with ethanol blends results in improved engine performance through increased brake power and thermal efficiency with significant reduction in pollutant emissions. Furthermore, Alvydas et al carried out a comparative investigation of the influence of ethanol blends on the performance and pollutant emissions of a Toyota Corolla engine. The results revealed an increase in octane number of the blended fuel alongside a decrease in the heating value of the fuel. The investigation further illustrated a slight increase in power output and SFC while CO and HC decreased but with CO_2 emission increasing as a result of improved combustion.In order to further establish its suitability of ethanol as an alternative fuel for powering our cars in Nigeria, this study is aimed at conducting an analytical evaluation so as to compare the characteristic performance of an automobile spark-ignition engine by using a variety of ethanol blends as fuel at variable operating conditions with PMS as the baseline fuel. The fuel flow, indicated power, brake power, indicated thermal efficiency, brake thermal efficiency and the friction power have been considered as the key performance indicators.

Table 1: Main characteristics of the investigated engine []

S/N	Parameter	Data
1	Bore X Stroke	81.00x86.40mm
2	No Of Cylinders	4
3	Cylinder Displacement	1781cc
4	Compression Ratio	10:1
5	Max Power	67.1kw @ 5200rpm
6	Max Torque	150nm @ 3300rpm
7	Bore/Stroke Ratio	0.94
8	Specific Output	50.5bhp/Litre

II. MATERIALS AND METHODS

2.1 The Test Engine Specifications

The engine used for this investigation is an Audi 80 (1.8S Sedan 1986 Model) spark ignition engine whose main characteristics are contained Table 1.In Table 2, the ratios of the investigated blended fuels, while

Table 3 reveals some selected physiochemical properties of the fuel.

Table 2: Ratios of the blended fuels

S/No	Designation of The Mixtures	Ratio of Ethanol to Gasoline	
		Ethanol (%)	Gasoline (%)
1	EO (PMS)	0	100
2	E 10	10	90
3	E 20	20	80

4	E 85	85	15
5	E 100 (Ethanol)	100	0

Table 3: Selected physicochemical properties of the investigated blends [2]

S/No	Property	Investigated Blends			
		E0	E10	E20	E85
1	Density (kg/dm^3@25^{0}C	0.7190	0.7290	0.7330	0.7885
2	Stoichiometric air/fuel ratio A/F (weight)	14.565	13.957	13.361	9.751
3	Lower heating value (KJ/Kg)	43500	41830	40160	29305
4	Research Octane Number (RON)	92.0	93.6	95.2	105.6
5	Motor Octane Number (MON)	82	82.7	83.4	87.9

Combustion Air Requirements

From literature [4], the theoretical Stoichiometric amount of air required for the complete combustion of 1kg of fuel is given as:

$$AFR=\frac{1}{0.23}\frac{\left(\frac{8}{3}C+8H-°F\right)kg}{kg}fuel \qquad (1.1)$$

However this amount of air is not always enough for complete combustion of the fuel such that an excess air coefficient (∝) is required to determine the actual amount of the air required for complete combustion of the fuel.

Actual amount of air required is given by [4]

$$\propto AFR = AAFR\frac{kg}{kg}fuel \qquad (1.2)$$

The fuel Air Ratio (FAR) is expressed as:

$$FAR = \frac{1}{AAFR} - \qquad (1.3)$$

Engine Performance Parameters

Engine performance has been defined as an indication of the degree of success with which the engine converts the chemical energy contained in the fuel into useful mechanical work [5] and the basic parameters of performance to be considered in this study therefore are:

Indicated power IP:

$$IP = (P_{mi}\ LAiK\ x\ 10)/6\ KW \qquad (1.3)$$

where P_{mi} = indicated mean effective pressure bar

L = length of stroke, m

A = area of piston, m^2

K = $\frac{1}{2}$ for 4 – Stroke engine (K = 1 for 2 – stroke engine)

I = Number of cylinders

Indicated Thermal Efficiency:

$$\dot{\eta}_{thi} = \frac{IP}{mfXLCV}\ kg/KWh \qquad (1.2)$$

where

m_f = Mass of fuel used, kg/s

LCV = Lower Calorific Value of fuel

Brake Power (BP):

$$BP = \frac{PmbX\pi\ D^2LNi}{8X10^3}\eta_m\ KW \qquad (1.3)$$

where:

P_{mb} = Brake mean effective pressure, N/m^2

D = Cylinder Bore

I = number of cylinders

Brake thermal Efficiency:

$$\eta_{thb} = \frac{BP}{m_f xLCV} \qquad (1.4)$$

Fuel consumption:

$$\frac{\left[nXAL\frac{N}{2}\eta_{vol}\right]X(Density\ \ of\ Air)}{AAFR} \quad (1.5)$$

where, $\eta_{vol} = volumetric\ efficiency$

Specific Fuel Consumption [6] SFC:

One of the most important parameters used to show fuel economy is given in terms of BP and IP as:

Indicated Specific Fuel Consumption: (ISFC) = $\frac{m_f}{IP}$ (1.6)

Brake Specific Fuel Consumption: (BSFC) = $\frac{m_f}{BP}$ (1.7)

Friction Power:

FP = IP – BP (1.8)

III. RESULTS AND DISCUSSION

Fig. 1 represents the pattern of the fuel flow for the different categories of ethanol blends under investigation. The curves have been designated as FF0, FF10, FF20, FF85 and FF100 corresponding to the respective ethanol blends E0, E10, E20, E85 and E100 based on its ration to the baseline fuel of the investigation, which was undertaken by powering the engine with these different blends in turns while the engine was considered to be running at increasing speed from 1000 rpm to a maximum of 5500rpm.In all cases, there was a steady and proportional fuel flow increase up to a speed of 5000rpm after which a slight decline was experienced as represented by the curves in Figure 1. Thereafter, it was observed that the rise in consumption continued up to the maximum investigated speed of 5500rpm revealing how pure ethanol (E100) flows more freely than the baseline fuel with a value of 0.007556kg/s at an engine speed of 5000rpm compared to that of PMS which with a lower value of 0.004754kg/s.

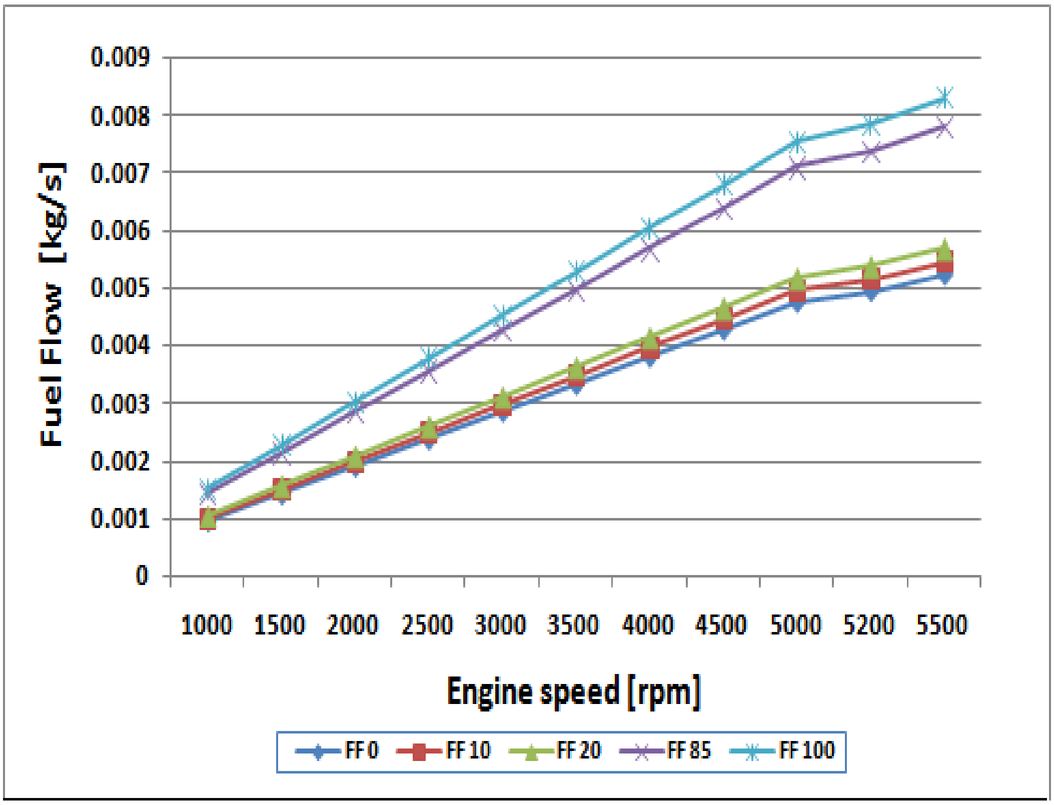


Figure 1: Analysis of the Fuel flow for the different blends

These fuel consumption rates show how it may be much more economical to power the engine with PMS than with the investigated blends of ethanol. The same pattern of fuel consumption followed the other blends when the investigation was extended to them and in conformity with previous research, the higher percentage of ethanol blends attracted higher values of fuel flow with increasing speed from which it may be concluded that a higher ratio of ethanol in the blends results in a lower calorific value (LCV). Curiously, the curves for E0, E10 and E20 show very little disparity when compared to those of E85 and E100 at lower engine speed settings.

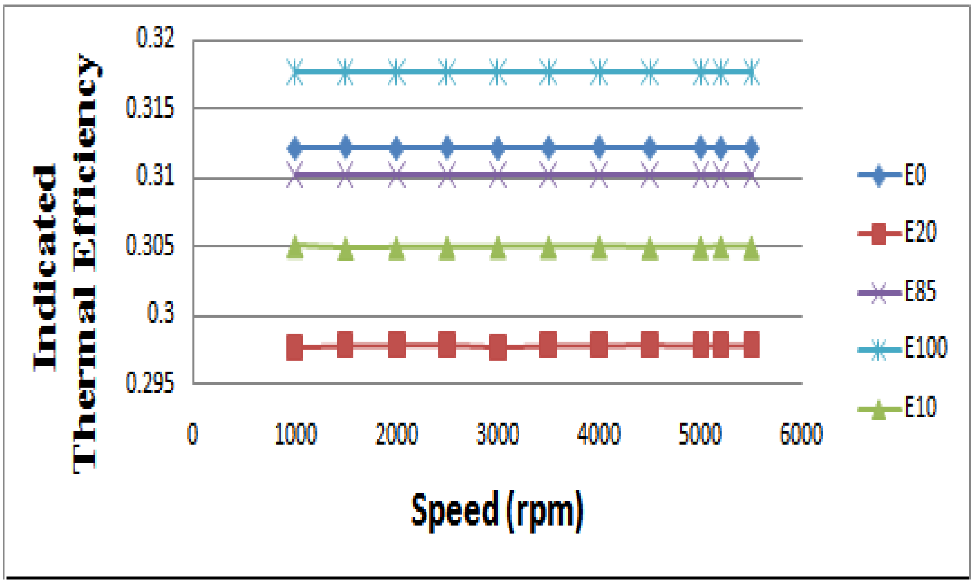
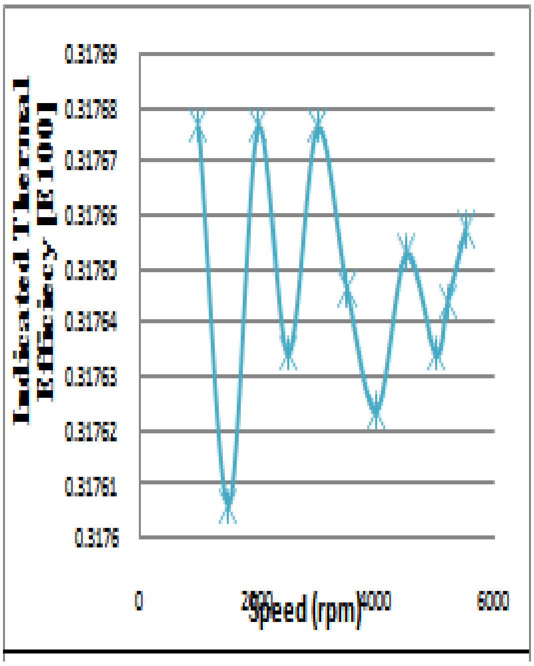


Figure 2: Variation of Indicated Thermal Efficiency for the variety of investigated blends

Fig. 2 plots the variation of the indicated thermal efficiency against the speed of the engine in which the unblended ethanol (E100) performs the highest thermal efficiency with the others following in the order of E0, E85, E10 and E20 respectively. Although the unblended ethanol demonstrated a higher thermal efficiency with an indicated value of 31.77% all through the speed range as against that of 31.22% for the E0 blend, the investigation showed that the performance of the engine using the E10 blend will give an indicated thermal efficiency of 30.50% while the E20 will generate a 29.78%. One of the conclusions emanating from this research is that it is very likely to obtain an optimized engine performance by using the E85 blend when compared with the other blends of the investigation. From the plotted results, it can also be concluded that the E20 blend is the lowest ITE and BTE and therefore the least suitable among the blends of the investigation as illustrated in all the plots for the evaluation of both indicated and brake thermal efficiency.



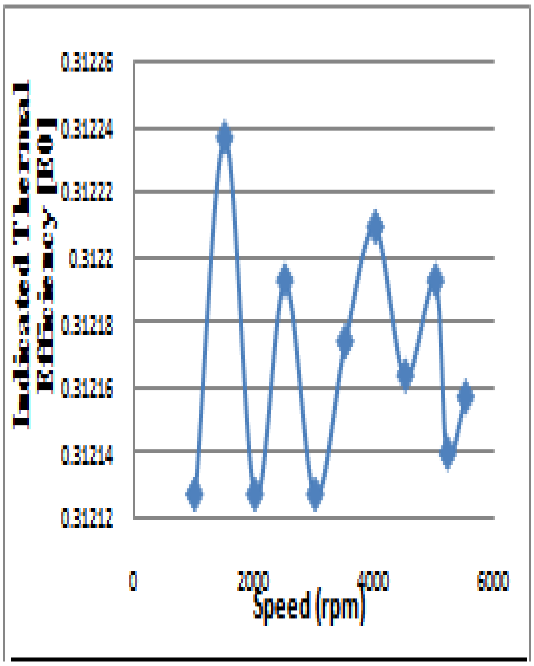


Figure 3: Indicated Thermal Efficiency variation for pure Ethanol (E100) and unblended PMS (E0) respectively

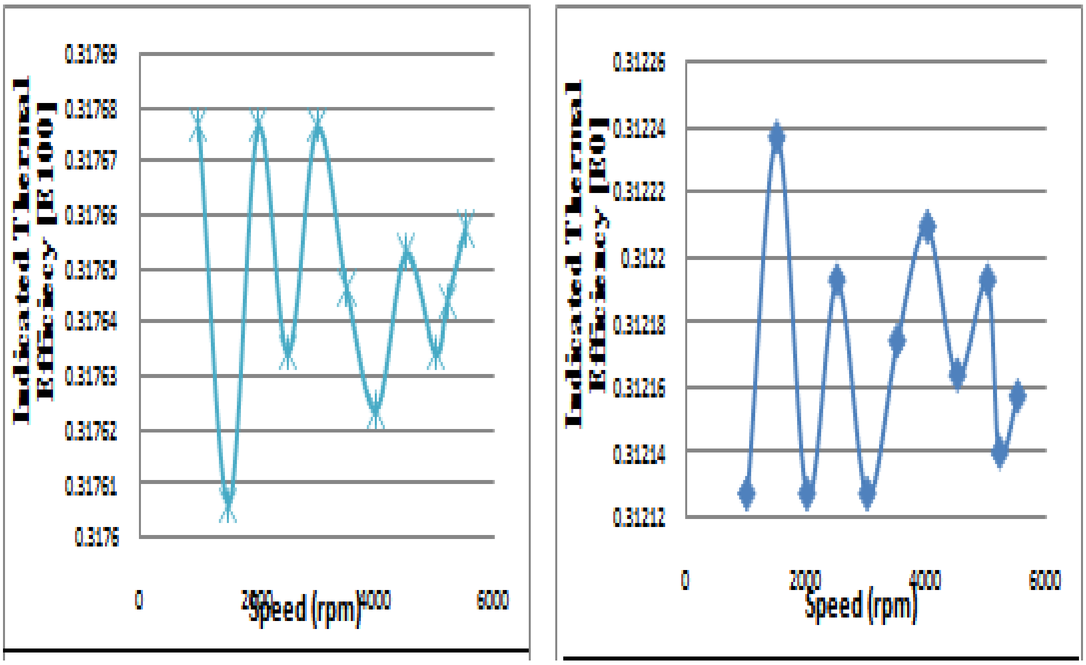


Figure 3 illustrates an expanded version of the engine performance curves of the indicated thermal efficiency comparing the use of the baseline fuel (E0) for powering the engine against that of the investigated blend of 100% ethanol (E100). In the illustration of Figure 2, the result shows a linear relationship all through from 1000rpm to the maximum speed of 5500rpm without revealing the embedded minor fluctuations that can be seen in

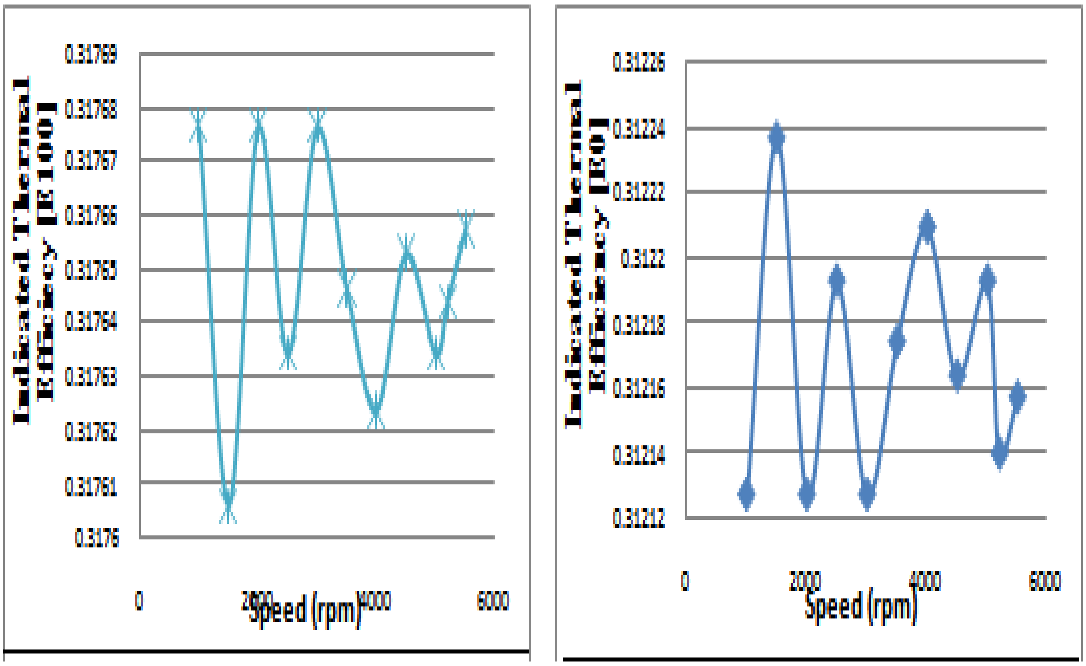


Figure 3. In comparison, this can be seen to be higher than the lower performance values of the indicated thermal efficiency obtained when the unblended baseline fuel was used. As illustrated in

Figure 5, the investigation was further conducted for the 10% and 20% blends and the results reveal a further decline in the indicated thermal efficiency fluctuating between 30.487% and 30.508% for the E10 at lower engine speeds while the E20 still indicated a linear representation of performance values between 29.76% and 29.78%.

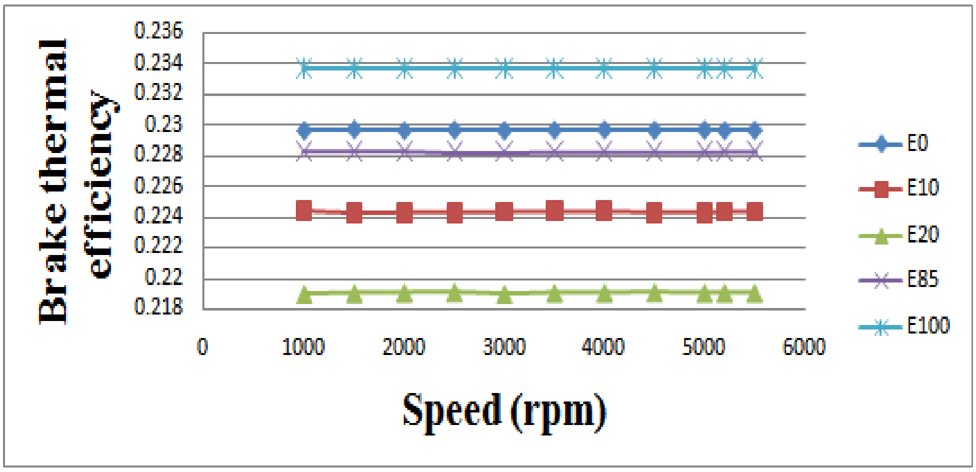


Figure 4: Variation of the Brake Thermal Efficiency for all the investigated ethanol blends

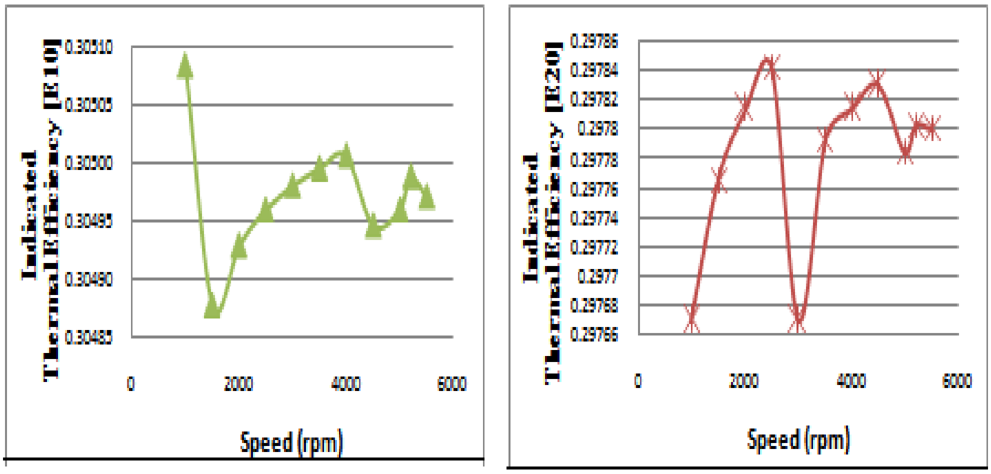


Figure 5: Indicated Thermal Efficiency variation for the blends of E10 and E20 respectively

In a similar fashion, the results from the investigation of the brake thermal efficiency can be seen as illustrated for pure ethanol and PMS without blending the two in And

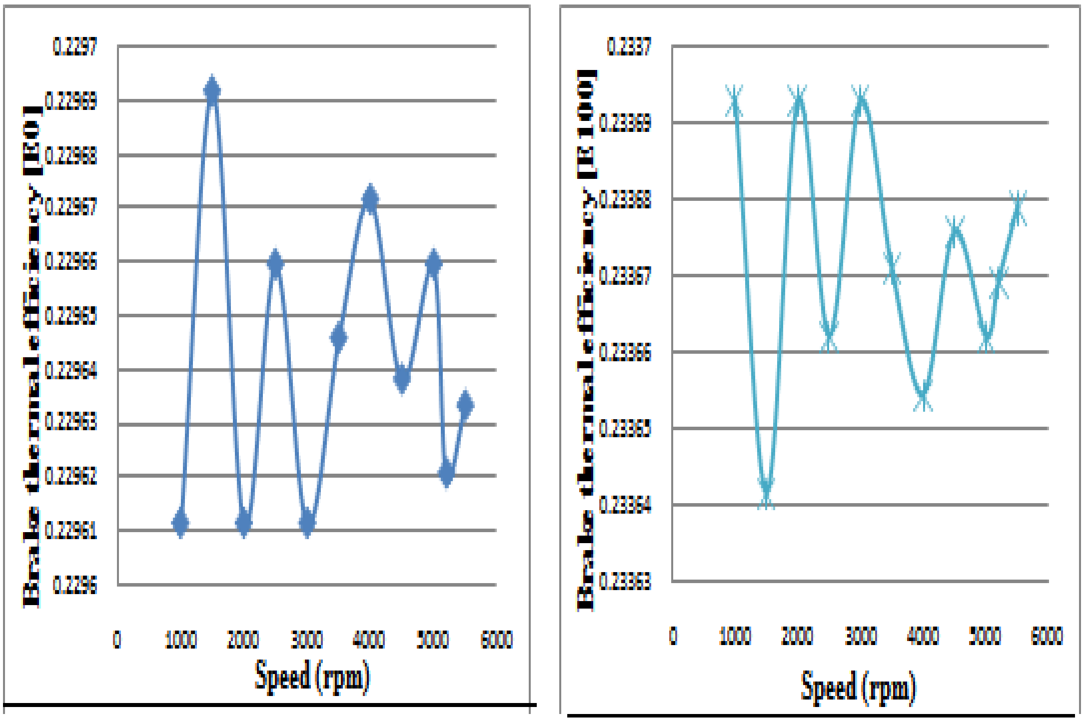


Figure 6. A closer examination of the two cases will shows the values for E0 fluctuating between 23.36% and 23.34% for pure ethanol while the PMS gave slightly lower values of BTE between 22.96% and 22.97% with the possible conclusion that a slightly higher BTE is possible with pure ethanol than with PMS.

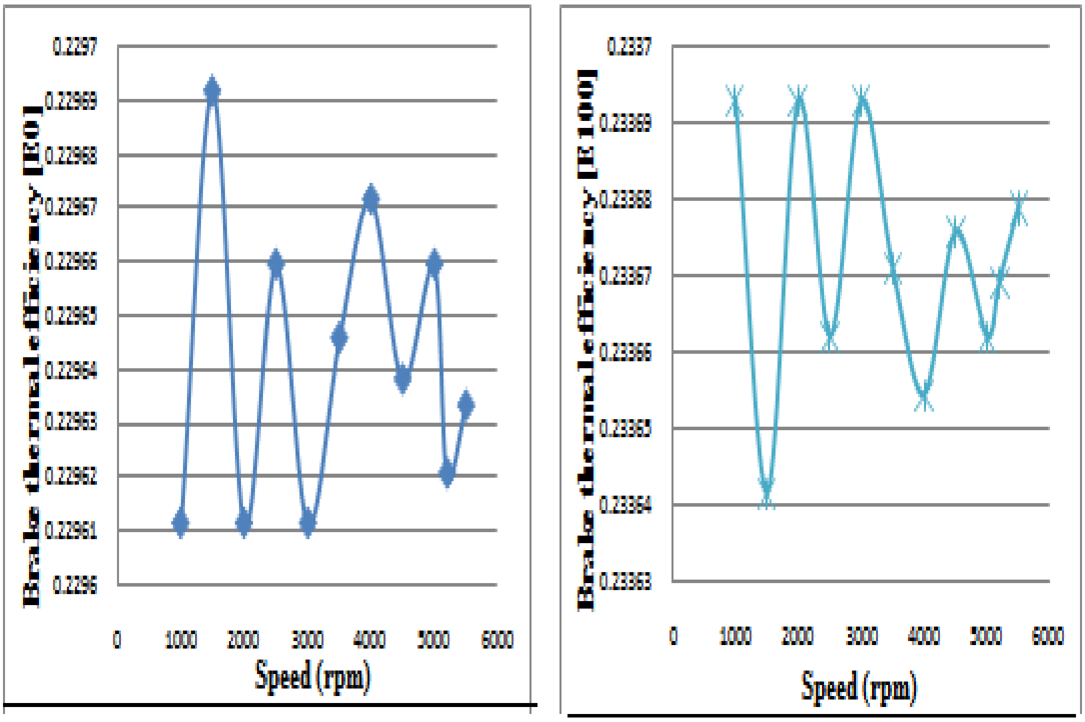


Figure 6: Comparison of the Brake Thermal Efficiency between the baseline fuel (E0) and unblended ethanol (E100**)**

A further investigation of the characteristics of these ethanol blends through an estimation of the relationship between the values of the engine's indicated, brake and friction power as illustrated in Figure 7

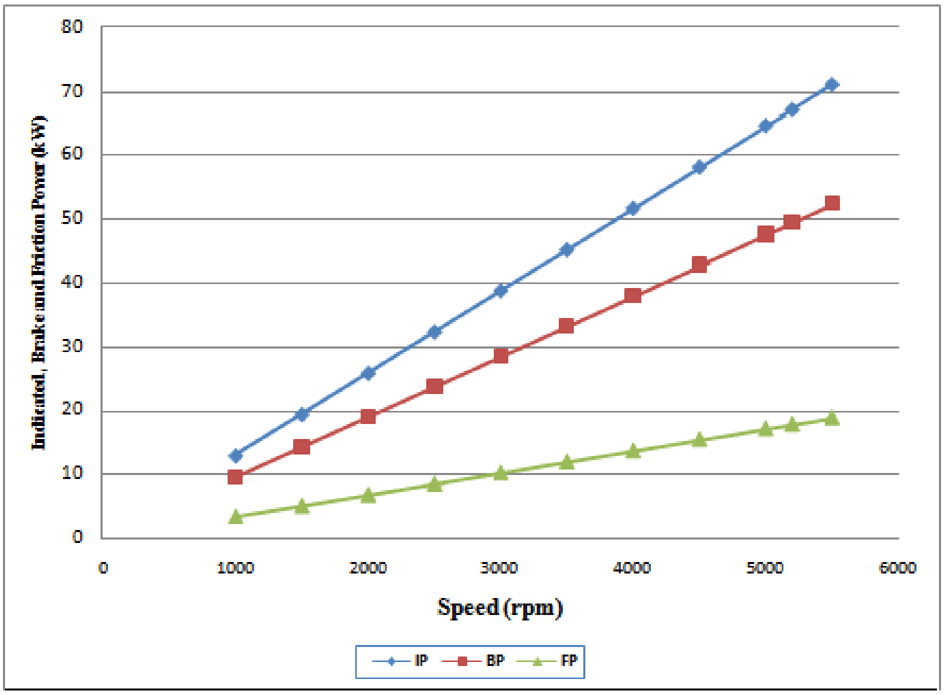


Figure 7: Analysis of the relationship between the Indicate Power, Friction Power and the Brake Power

It can be observed that the IP, BP and the FP increased with increase in speed and naturally, the value of the IP was found to be higher than that of the brake power taking as a major factor the role of the friction absorbed through the friction power FP. This observation is in agreement with several works in literature that not all the power which is generated in the cylinder is delivered at the drive shaft because of frictional losses [4, 6]. The above illustrate that the IP at a peak of 71KW, is higher than the brake power while the BP has a peak of 52KW. The difference between the two is 19KW which represents the FP. Similarly minimum values for these parameters were found to be 13KW, 9KW and 4KW respectively. Therefore, from the aforementioned the engine was found to develop more indicated power for any given speed than the brake power since friction power is the difference in indicated and brake powers available within the engine. From the point of view of this investigation the losses incurred in terms of indicated and brake powers are fairly minimal.

II. CONCLUSIONS

Although petrol (PMS) is well known to be the conventional fuel that has dominated the powering of spark-ignition engines the world over, this research has further evaluated the behavior of a spark-ignition engine when powered by pure ethanol or its blends with PMS. In this study, it has been shown that the blending of ethanol has a tendency of increasing the running cost for the motorist depending on the grade of blending. This may also depend on the availability of refined ethanol in commercial quantities enough to favorably compete with existing stock of PMS. The values of both indicated and brake thermal efficiencies have been found to be slightly higher owing to the low calorific value of ethanol compared to the baseline fuel under investigation.

REFERENCES

[1]. www.thefreedictionary.com/automobile. Accessed 20/12/13

[2]. C.O. Folayan, Prospects and challenges of automotive design and development in Nigeria in the next millenium : A lecture delivered during the Nigerian society of engineers (NSE) Kaduna branch monthly meeting 25/09/1999.

[3]. Official gazette of the Nigerian bio-fuel policy and incentives, Federal Republic of Nigeria 2007

[4]. D Borah and V Mishhra, Production of fuel from fruit waste, International Journal of Advanced Biotechnology Research, 1(1), 2011, 71-74.

B. A. Adelekan, Investigation of ethanol productivity of cassava crop as a sustainable source of biofuel in tropical countries, African Journal of Biotechnology, 9(35), 2010, 5643-5650.

[5]. W. C. Solomon, M. U. Bonet and S. U. Mohammed, Performance Investigation 0f a 650W Domestic portable electric generator power generator using ethanol as an alternative fuel, International Journal of Engineering Research and Technology, 2(10), 2013,3845-3850.

[6]. A. Cernat and S. Velescu , Bioethanol a viable alternative fuel for spark ignition engines, Thermotechnica Journal, 2,2013, 110-118.

[7]. V. S. Kumbhar, D. G. Mali, P. H. Pandhare, and R. M. Mane, Effect of lower ethanol gasoline on performance and emission characteristics of the single cylinder SI engine, International Journal of instrumentation, control and automation, 1(3), 2012, 51-54

[8]. V. Piris, D. Berjoza, G. Birzietis and I Dukulis, Fuel consumption Studies of spark ignition engines using blends of gasoline with Bioethanol, Agronomy Research , 2010, 208-215.
[9]. A. Cernat and S. Velescu (2013) Bioethanol a viable alternative fuel for spark ignition Engines, THERMOTHECHNICA pg 110-118 2/2013
[10]. V. Pirs,D. Berjoza,G. Birzietis, and I. Dukulis, Fuel consumption studies of spark ignition engine using blends of gasoline with Bioethanol,
[11]. C. Shane, O. Mark, H. Terrace, and E. Scohe (2008), Effect of Ethanol Blends on a Spark Ignition, 4- Stroke Engine, Internal combustion Engine" Bringham Yound University, Provo, Utah December 5, 2008
[12]. K. Jitendra, N. A. Ansari, V. Vika, and K. Sanjecv, Exhaust Gas Analysis and parametric Study of Ethanol Blended Gasoline Fuel in Spark ignition Engine, American Journal of Engineering Research (AJER,) 2(7), 201, 191-201
[13]. T. A. Farha,P.V. Abhishik, and C. Alok, Effect on performance and emission of spark ignition engine using ethanol as blend fuel under varying compression ratio, International Journal of Engineering Research and Technology (IJERT), 2(12), 2013,
[14]. P. Alvydas, P. Saugridas, and G. Juozas G (2013, Journal of KONES Internal Combustion Engines Vol 10, pg 3-4.

WC Solomon."An Analytical Performance Investigation Of A Spark-Ignition Automobile Engine While Using Ethanol Blends As Fuel.." American Journal of Engineering Research (AJER), vol. 7, no. 1, 2018, pp. 288-297.