Evaluation of Spark Ignition Engine Performance Using Ethanol as Doping Agent on Constant Speed Test.

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Keywords: BSFC, Brake Power, Brake Thermal Efficiency, Fuel Flow Rate

Abstract. Engine knock is a critical phenomenon engine designers strive to minimize in the world today. Before now, this has made tetra ethyl lead (TEL) an option for minimizing knock. The basic essence of tetra ethyl lead is to enhance octane rating of petrol which is a vital factor to knocking ability. However, the health and environmental challenges associated with the use of tetra ethyl lead propel the desire to replace it with a better environmental and health friendly substance that will at the same time boost octane rating and give a smoother engine operation. Hence, ethanol was considered in this work at a constant speed test of 2000 rpm and compared to leaded petrol as baseline petrol. BSFC of 0.703 kg\kWhr was obtained with 20/80 compared to 0.709 kg\kWhr obtained with 0/100 as baseline fuel. Maximum brake power of 0.74 kW occurred at a bmep of 1.235 bar with 15/85 ethanol/petrol. Similarly, maximum brake thermal efficiency of 13.44% was obtained with 20/80 ethanol/petrol compared to 11.49% obtained with leaded petrol as baseline petrol. It is indicated that maximum power output, low BSFC and low petrol consumption was obtained with 20/80 ethanol/petrol blend. It is convincible that 20/80 blend ratio offer good alternative to other antiknock agents which are associated with harmful consequences to man and environment. The implication of this work is that a definite blend for optimum performance and more environmentally friendly antiknock agent is established.

1. Introduction

The global issue of rapid reduction of petroleum fuels and their associated problems lead to extensive search for an alternative doping agent in place of the present doping agents. The key objective in this paper is to obtain a petrol/ethanol blend ratio that will give an optimum engine performance at constant speed condition. Thomas Midgeley Jr noticed the absence of unpleasant noise called engine knock when running on petrol doped with TEL.^[5] But unfortunately the risk associated with the use of the lead compound propelled the desire to seek for an alternative friendly antiknock doping agent in place of TEL. Hence it is a fruitless effort to obtain a solution to engineering challenges at the expense of environment and component suitability. According to USA Environmental Protection Agency, Lead exposure to human leads to gastrointestinal symptoms, brain and kidney damage, reproductive defects, cancers and so on. It further pointed out that early childhood and parental exposure causes slow cognitive development, learning plus other deficits^[15]. Basically, engine knock is a resultant of abnormal combustion taking place in cylinders of engines due to pressure oscillations which culminate to engine cycle efficiency deterioration, dramatic increase in exhaust emission, as well as metallic pinging noise.^[6] Usually the unburnt gases are compressed by the advancing flame front, which raises the temperature to a point of self-ignition and this result to an uncontrolled combustion, which is heard as engine knock sound. High engine knock could result to reduction of engine lifetime and damage of engine. More effects of engine knock are fracture of piston crown, cracks and rings grooves due to shock waves, melting of edges, high carbon deposits, piston seizure, low power output and efficiency. Oxygenates are among the effective ways of improving performance of any fuel^[3]. Azubuike and Nwafor (2015) studied the performance of unleaded petrol

doped with ethanol running on S.I engine at constant load condition and found out the critical reasons for advocating ethanol as an antiknock agent are due to its environmental friendly nature, availability, high fuel density, high octane value and low calorific value associated with ethanol. Minimum octane number requirement prevents engine knock and gives smooth engine operations. Ethanol was the first fuel among the alcohols to be used to power vehicles in the 1880s and 1890s ^[3] ^[9]. Henry Ford presented it as the fuel of choice for his automobiles during their earliest stage of development ^[3]. The engine performance with ethanol doped with petrol was seen to be better. However, the test condition was not specified. At low loads, engine performance with petrol doped with toluene was better than with pure petrol ^[11]. Mohd *et al* (2016) reported that performance characteristics showed that petrol doped with 20% ethanol performed better than pure petrol at all loads. It was revealed that use of ethanol completely and correct change of the spark timing could be a promising approach to enhance efficiency and environmental state of spark ignited engine ^[11]. It pointed out that for 5/95 blend from *Salvinia molesta* Bioethanol, there is no significant improvement in performance analysis compared to that using Petrol ^[12]. According to United State Department of Energy, Ethanol usually oxygenate the petrol more when it is blended with petrol thereby reducing air pollution. ^[16] Chan-Wei *et al* (2004) in their engine test performance showed that CO and HC emissions were reduced as ethanol content in blend increases. ^[2] It indicates an oxygen enrich fuel and affirm how environmental friendly petrol/ethanol blends are.

2. Instrument and Experimental Procedures

2.1 Instrument

At the cause of the experiment some material were used such as leaded petrol, unleaded petrol and ethanol blend, funnel and fuel hose and switch, tachometer, dynamometer, test tube, measuring cylinder, and reagents.

The unleaded petrol used was acquired from a refinery in Nigeria. The ethanol was extracted from woodchips (sawdust) from sawmill within Owerri Metropolis. The sawdust was subjected to saccharification process (Simultaneous Saccharification and Fermentation) to convert to glucose which ferments further to give out ethanol. These blends: 0/100, 5/95, 10/90, 15/85, 20/80, 30/70 and 40/60 (ethanol/petrol by volume) were characterized in line with America Standard for Testing and Material (ASTM) methods.

Engine Specifications

Bore	68 mm
Stroke	45 mm
Compression Ratio	8.5/1
Fuel Tank Capacity	3.6 litres
Number of Cylinder	1
Cooling Medium	Air
Engine Capacity	196 CC

2.2 Experimental Procedures

A test rig was set up involving single compression ratio spark ignition engine. It was mounted with other auxiliary components needed for the experiment. The test was conducted at a constant engine speed of 2200 rev/min using different fuel blends. For each blend and load, fuel consumption rate, and torque were measured. Loads of values 9.81 N, 19.62 N, 29.43 N, 39.24 N and 49.05 N were considered. A schematic diagram of the engine test rig fuel flow system is shown and represented in figure 1.

A digital tachometer was used to measure the speed, flow rates of petrol were captured from a glass tube and were used to compute brake power (bp) as shown in equation (1) below, brake thermal efficiency (bte) as shown in equation (4), brake specific fuel consumption (bsfc) as shown in equation (3) and brake mean effective pressure (bmep) as in equation (2). These computed data were obtained using the following relations.

$$bp = 2\pi NT \quad (1)$$

$$bmep = bp \times 60000 / ALNn \times 10^5 \quad (2)$$

$$bsfc = M_f / bp \quad (3)$$

$$bte = bp / \text{energy supplied} \quad (4)$$

Figure 1. Engine Test Rig Fuel Flow System

Table 1. Characterization Result of Unleaded Petrol and Blends

Sample	Density at 29°C	Octane No.	Flash Point °C	Calorific Value (MJ/Kg)
Unleaded Petrol	746.70	93.20	-65	44.30
5/95	747.10	95.10	-54	43.80
10/90	748.20	97.20	-40	41.80
15/85	752.00	98.60	-36	41.20
20/80	761.30	100.40	-20	38.10
30/70	775.60	102.70	-15	37.70
40/60	780.20	106.30	-13.5	37.40

Source: Azubuike and Nwafor (2015)

Azubuike and Nwafor (2015) opined from their related work done on variable load conditions that increase in ethanol percentage in the blends at 29°C condition increased density of leaded petrol at

746.70kg/m³ to 780.20kg/m³ for 40/60 ethanol/petrol by volume which represents about 4% increment. Octane number increases in same trend as ethanol/petrol percentage increases. This increase of octane number is known to improve the antiknock quality of the fuel. Calorific value shows the energy transferred as heat to the surrounding per unit quantity of fuel when burn at constant pressure and Table 1 shows a gradual decrease of calorific value as ethanol percentage increases. According to Kheiralla et al (2011), properties of the fuel from the result of test show that blend densities and kinematic viscosity increased continuously and linearly with increasing percentage of ethanol. Heat values was observed to decrease with increasing percentage of ethanol. [8]

3. Results

3.1 Effect of Blends on BSFC at Constant Speed of 2200 rev/min

The graph on figure 2 below show the engine performance relationship of BSFC and BMEP of various blends in comparison with 100% lead doped petrol.

Figure 2. Graphs of BSFC against at BMEP at Constant Speed of 2200 rev/min

The trends indicates that bsfc being dependent on fuel flow rate and brake power, decreases with bmep to a lowest point before increasing with increase in bmep. From the superimposed graphs figure 2, the lowest point of each blend indicates the best fuel economy when running at the same conditions. From figure 2, at constant speed test of 2200 rev/min, the lowest bsfc of 0.703 kg/kWhr occurred with 20/80 ethanol/petrol blend. When compared with other blends and the baseline petrol with a minimum bsfc of 0.709 kg/kWhr at 2200rev/min. It gave an engine power with less fuel consumption. The superimposed graphs indicate that lower bsfc was obtained as the percentage of ethanol increases in the blends. At the lowest bsfc value on the graphs, it means that enough air was available for complete combustion. This is due to oxygen atom contained in chemical formula of ethanol ($\text{CH}_3\text{CH}_2\text{OH}$), which aid combustion. Khan and Nath (2007) found out from experiment that of S.I engines running on blend ratio 15% ethanol and 85% petrol had a slight lower BSFC than 100% petrol and it has further validate the above result presented. [10]

3.2 Effect of Blends on Brake Power at Constant Speed of 2200 rev/min

Figure 3 below show the engine performance relationship of BP and BMEP of various blends in comparison with 100% lead doped petrol.

Figure 3. Graphs of Brake Power against BMEP at Constant Speed Test of 2200 rev/min

Figure 3 shows a maximum brake power of 0.74 kW occurring at a bmeep of 1.235 bar with blend of 15/85 ethanol/petrol at a constant speed of 2200 rev/min. This decrease in brake power developed at 2200 rev/min suggests that brake power depend on engine speed and torque. This indicates that the breathing capacity (volumetric efficiency) of spark ignition engines declines beyond certain engine speed as torque drops.

3.3 Effect of Blends on Brake Thermal Efficiency at Constant Speed of 2200 rev/min

Figure 4 indicates the relationship of bte and bmeep at a constant speed.

Figure 4. Graphs of Brake Thermal Efficiency against BMEP Constant Speed of 2200 rev/min

Brake Thermal Efficiency is the ratio of brake power to heat energy supplied and it indicates the ability of an engine to convert petrol energy into useful power output. Figure 4 above shows that brake thermal efficiency (bte) increases with rising bmeep. With constant speed test of 2200 rev/min, the maximum brake thermal efficiency occurred with 20/80 ethanol/petrol with a value 13.44% and 11.49% with 100% leaded petrol. The increase is due to decrease of calorific value of 20/80 blend.

3.4 Effect of Blends on Fuel Flow Rate at Constant Speed of 2200 rev/min

The graph in figure 5 below show the relationship of flow rate with BMEP at a constant speed.

Figure 5. Graphs of Fuel Flow Rate against BMEP at Constant Speed of 2200

Figure 5 shows that bmeP acting on the piston increases as the fuel flow rate increases. The lowest fuel consumption of 0.321 kg/hr was obtained when running on blend 20/80 at a speed of 2200 rev/min. Fuel consumption increases with increase in bmeP so as to sustain the power requirement of the engine.

4. Conclusion

The results obtained on constant speed test at 2000 rpm when running on petrol doped with ethanol indicated that maximum brake power output, low BSFC and low fuel consumption were obtained with 20/80 ethanol/petrol blend. They show that 20/80 ethanol/petrol blend by volume can offer good alternative antiknock fuel devoid of TEL as antiknock agent. It raises confidence that with ethanol blend in petrol as antiknock, our environment and health can be sustained with better engine performance.

Conflict of Interest Statement

The research results presented in this paper is the original work of the Authors. The Authors declares that there is no conflict of interest of any kind.

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