International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 1877-1888 www.ijaem.net ISSN: 2395-5252

# Effects of Load on Gaseous Emissions of Gasoline and Ethanol Blends in a Single Cylinder Production Engine

Precious Emesomi James[1], Mohammed Moore Ojapah[*1], Celestine Ebieto Celestine[1], Ogheneruona Diemuodeke[1], Ofodu Joseph Chukwuka[1] and Nehemia Sabinus Alozie[2]
[1]*Mechanical Engineering Department, University of Port Harcourt, Nigeria*
[2]*Mechanical Engineering Department, University of Lagos, Nigeria*

Date of Submission: 20-03-2023 Date of Acceptance: 30-03-2023

**ABSTRACT:**
The internal combustion engines are the most broadly applied and widely used power-generating devices currently in existence. Examples include gasoline engines, diesel engines, gas-turbine engines, and rocket-propulsion systems. The emissions of unburnt hydrocarbon (UHC), oxides of nitrogen ($NO_x$), carbon monoxide (CO), and carbon dioxide ($CO_2$) from internal combustion engine have been seen to cause negative environmental impact and a major source of greenhouse gas effect. This has lead to more stringent emission legislation, and even a total ban of use of fossil fuel based internal combustion engine timeline already set by some advanced countries. This investigation is being carried out to provide better understanding and identifying strategies for use of alternative fuel that is locally produced to reduce emissions and to create wealth for the locals, in addition to improve the quality of learning and teaching in engineering. Thereby enabling better and more robust advises to the Nigerian government policy makers on use of alternative fuel either in a blend form or neat biofuel use and the urgent need to further continued the abandoned development of the piston started over ten years ago. An experiment was carried out on a single cylinder carburetor type domestic portable power generating set of fixed speed and MBT spark timing, using blends of 15% ethanol and 85% gasoline (E15) and 50% ethanol and 50% gasoline (E50) under varying engine loads. It was observed from the result obtained using blends of locally produced ethanol and gasoline led to an increase in NOx and $CO_2$ emissions but decreases the CO and UHC emissions, for the same loading increased fuel consumption was observed for E15 and E50. In addition, this has provided a platform for experimental work on reciprocating engine for the undergraduates and graduate students of the department and further increased student interest in the field of automotive engineering, fuel and lubricants

## I. INTRODUCTION

In recent time there has been an interest in improving the quality of teaching and learning in engineering education across the globe. There is also the worry of poverty level in sub-Saharan Africa due to our population with higher percentages being youth. Currently the highest employer of labour in sub-Saharan Africa is the farming sector, and Nigeria being the most populated country in the region has the highest unemployment rate. In addition, the manufacturing sector of the country has witnessed a decline in recent time. This coupled with the our foreign reserve that is continuously shrinking there is an urgent need to look into the sector that can really mitigate these challenges. According to (Alex Covarrubias V. and Sigfrido M. Ramírez Perez, 2020), the “global auto industry revenues reached $3.8 trillion in 2018 after growing at an annual rate of 3.3% for the last five years. Which means that if the automotive manufacturing industries were a country, it would be the fifth largest economy in the world, after the United States (with a GDP of $20.4 trillion), China (14), Japan (5.1), and Germany (4.2)”. This information tells or gives us the idea of the contribution of the automotive industry the national economy of any nation. For each job creation in the automotive industry there is an additional job being created. The internal combustion engine has played a significant role in the automotive industry in the course of human development as man has attempted to find means for long distances transportation, portable power generation, and the propulsion of heavy duty vehicles and marine transportation. The internal combustion engine has been with us for more than 150 years. According to (John Benjamin Heywood, 2018), it is an engine whose energy is released by burning or oxidizing the fuel inside the engine. A lot of studies have shown that motor vehicles are the major contributors of local emission, and the major source of greenhouse gases such as carbon dioxide (CO2), Oxides of Nitrogen or Nitrogen Oxides (NOx), unburnt hydrocarbon (UHC), and carbon monoxide (CO) which result from incomplete combustion of fuel used in engine. These emissions Increases the risk of global warming and affects society globally and locally in form of acid rain, and health effect. In the mean time, the limited availability of fossil fuel has necessitated the needs for an alternative and sustainable fuel. There has been a robust research on new generations of combustion engines and fuel by the automotive researchers and industries. However, with the stringent emission legislations and the move away from fossil fuel towards electric and fuel cell powertrain, there is an urgent need for an alternative fuel that will be sustainable and readily available in the short term. In addition, this powertrain and fuel should contribute to knowledge and skill, employment and wealth creation locally.

The greatest challenge with gasoline and diesel fuel engines is the emission which increases day by day due to increasing number of vehicles on our roads and the power generating sets for domestic and small businesses in Nigeria and other regional countries. With increasing demand and depletion in fossil fuels reserves there's increased concern for the security of the oil supply and the negative impact of fossil fuels on the environment, particularly greenhouse gas emissions. In addition, the reliance on foreign refined fuel is also of great concerns. The $CO_2$ legislation due to global warming has mandated the development of more efficient IC engines. All these have put pressure on society to find renewable fuel alternatives. Renewable energy is one of the most efficient ways to achieve sustainable development. Increasing its share in the world matrix will help prolong the existence of fossil fuel reserves, address the threats posed by climate change, and enable better security of the energy supply on a global scale (Goldenberg, 2007)

There's a major challenge for increase in energy consumption. Biomass is an untapped energy source in form of plant and animal materials that can be solid fuels such as firewood, charcoal, wood pellet, crop residue, animal waste etc. or liquid fuels such as ethanol, methanol and biodiesel. As fossil fuels becomes more depleted and more expensive, biomass is beginning to attract greater attention as an alternative energy source, and with bioethanol which is particularly a useful biomass fuel that have a wider applications such as its high octane number, it's easy blending with gasoline used in existing internal combustion engines such as in power-generating set and motor vehicles will be a great alternative to reduce engine emissions and also create local wealth for the local farmers and individuals who will be highly involved in the production of ethanol locally (Eze, 2004)

Engine emissions results from incomplete combustion of fuel used in engines, it comprises of UHC, that is emitted during combustion of fossil fuel as a result of incomplete combustion, the NOx that are formed as a result of high temperature combustion in engines. The nitric oxide (NO) and nitrogen dioxide (NO2) are grouped together as NOx emissions. Nitric oxides are responsible for acid rain and nitrous oxide and they contribute directly to global warming. Nitrogen dioxide is toxic and is known to cause and aggravate human respiratory disease. The CO is produced as a result of rich fuel and air mixture preparation in the combustion chamber. The CO formed in combustion process is then oxidized to $CO_2$ at slower rate. Carbon monoxide is dangerous to human health in the following ways, it causes respiratory condition and heart disease, and it also combines with the blood and hinders the body ability to absorb oxygen. The CO2 is nontoxic, high emission of $CO_2$ is an evidence of good Combustion, but it has environmental effect as it enhances greenhouse effect. The $CO_2$ constitute 85% of emissions from motor vehicles.

However the sources of the above pollutant vary and depend on the engine operating conditions and type of fuel used. There are many ways to realize efficient and less polluting or cleaner transportation, the most common renewable fuel today is ethanol produced from sugar or grain (starch), jatropha and sea weeds or algae. Ethanol has physicochemical properties similar to gasoline but has clean emission as compared to gasoline for same engine output power (Srivastava et al, 2018).

Ethanol is an attractive alternative fuel because it is a renewable bio-based resource and it is oxygenated, thereby providing the potential to reduce particulate emissions in engines (Hansen, 2005)

Ethanol is known as the most suitable renewable, bio-based and ecofriendly fuel for spark-ignition (SI) engines. The most attractive properties of ethanol as an SI engine fuel are that it can be produced from renewable energy sources such as sugarcane, cassava, nonedible plants, biomass materials, corn and barley.

Ethanol has high octane number, high latent heat of vaporization than that of gasoline (which lowers the combustion temperature) thereby producing charge cooling effect in the combustion chamber, high flame speed, higher oxygen content, low sulphur content, less calorific value which means high fuel air ratio required for complete combustion. Therefore it has positive influence on engine performance and reduces exhaust emissions (Mustapha Koc, 2009). Ethanol increases the engine performance by increasing volumetric efficiency, thermal efficiency, but the specific fuel consumption increases because ethanol has less calorific value as compared to gasoline. Hence, more ethanol is required for usage to cover the same mileage or load compared to using pure gasoline.

Alternative fuel will become more common in coming decades because there’s need for concentrating on cleaner and more efficient engines. Using an alternative fuel such as ethanol and gasoline blends will result in a significant drop in greenhouse gas emissions. In addition, it will also generate income for the locals. The ethanol fuel has the potential to mitigate greenhouse gas, it has physicochemical properties similar to gasoline but improved emissions compared to gasoline for same engine power output. In addition, it extends the knocking limit of the engine due to its high octane number, and the high latent heat of vaporization lowers the combustion temperature.

In response to the above challenges the this investigation is to experimentally study the emission from gasoline ethanol fuel blend in low to medium percentages in domestic power generating set. These are engines that are common households and small businesses as well as in 2- and 3-wheeler transportation vehicle engines in Nigeria.

The internal combustion engine is the most popularly used propulsion devices in Nigeria, other sub-Saharan Africa and the developing world generally, they emits exhaust gases as product of combustion, the harmful emissions produced can be controlled by improved fuel quality, better atomization of fuel, use of exhaust gas recirculation (EGR). The EGR is a method that is used to keep combustion temperature below critical figure so as to reduce the NOx emissions.

Recent development of spark ignition engines includes the gasoline direct injection (GDI) and engine downsizing, because of its potential to economize fuel and performance. The GDI was first applied by Mitsubishi to improve power output. However, to date the portable power generating set has increased in number in Nigeria massively due to the unreliable power supply and the high initial capital for the solar PV power generating set, but the technology is still the same using carburetor as the fuel preparation method.

As another alternative fuel, blending ethanol with gasoline is quite promising, studies has confirmed that ethanol in gasoline engine increases the engine (energy) efficiency, torque and power compared to using pure gasoline. As a substitute for fossil fuel, ethanol is a renewable fuel and can be produced from several biomas. It has unique properties such as high octane number and it is the largest alternative transportation fuel (Larsen et al, 2009).

Several studies have been carried out by so many researchers on ways to improve engine performance and emission. An experimental comparism has been carried out on 4- and 2-strokes combustion engines using ethanol in varying percentages with gasoline blends. The effect of ethanol in different combustion modes have been analyzed using varying load and speed (Ojapah M M, 2014).

Abel-Ramah et al. (1997) investigated the effects of different ethanol-gasoline fuel blends up to E40, under variable compression ratio conditions. They used a variable compression engine to study the effect of varying the compression ratio in SI engine. The results show that the engine indicated power improves with the addition of ethanol in the fuel blend. The maximum improvement occurs at E10 fuel blend.

Hsieh et al. (2002) experimentally investigated the engine performance and pollutant emission of a commercial SI engine using E0, E5, E10, E20, and E30. Their result showed that increasing the ethanol content, the heating value of the blended fuel decreased, while the octane number of the blended fuel increases. The results of the engine test indicated that using ethanol-gasoline blends, torque output and fuel consumption of the engine slightly increases. The CO and HC emission decreases as a result of the leaning effect caused by the ethanol addition. The $CO_2$ emission increases because of the improved combustion, which they attributed to improved combustion and the oxygenation nature of ethanol. In addition, they observed that NOx emission depends on the engine operating condition rather than the ethanol content.

Al-Hassan (2003) investigated the effect of using gasoline-ethanol blends in a 4-stroke 4 cylinder Toyota Tercel-3A SI engine. The performance and the emissions of CO, CO2 using different percentages of fuel blend at 75% throttle opening position setting were analyzed. The engine speed was varied from 1000 to 4000 rpm. The results showed that blending unleaded gasoline with ethanol increases the brake power, torque, volumetric and brake thermal efficiencies, and fuel consumption. The CO and HC emissions concentrations in the engine exhaust were observed to decrease, while the CO2 concentration increases. The use of E20 gave the best results for all measured parameters at all engine operational speed used.

Bayraktar (2005) investigated the effects of ethanol-gasoline blend on an quasi-dimensional SI engine performance and exhaust emissions using E1.5, E3, E4.5, E6, E7.5, E9, E10.5 and E12 up to E21 at 1500 rpm for each blend with compression ratios of 7.75 and 8.25 and at full throttle setting. Their results showed that among the various blends E7.5 was the most suitable blend from the engine performance and CO emission. However, theoretical comparisons have shown that the blend containing E16.5 ethanol was the most suited blend for SI engines.

Celik (2008) investigated the effects of E0, E50, and E85 on engine performance and pollutant emissions in a 1-cylinder 4-stroke spark-ignition engine using two compression ratios of 10:1 and 11:1. The engine speed was varied from 1500 to 5000 rpm at wide open throttle (WOT). The results of the engine test showed that ethanol addition to gasoline increase the engine torque, power and fuel consumption and reduces the CO, NOx, and HC emissions. They also observed that ethanol-gasoline blends allow increasing compression ratio (CR) without knock occurrence.

Najafi et al. (2009) investigated the effects of ethanol-gasoline blends of E0, E5, E10, E15 and E20 performance and the pollutant emissions of a 4-stroke SI engine with the aid of artificial neural network (ANN). The properties of bioethanol were measured based on American Society for Testing and Materials (ASTM) standards. Their experimental result shows that using ethanol-gasoline blends increased the power and torque output of the engine marginally. They also observed that the brake specific fuel consumption (bsfc) decreased while the brake thermal efficiency and the volumetric efficiency ($\eta v$) increased. Their measured concentration of CO and HC emissions in the exhaust pipe decreases in using ethanol blends. This was likely due to the high oxygen percentage in the ethanol. In contrast, the concentration of CO2 and NOx was found to increase when ethanol was introduced.

Costa et al. (2010) investigated the performance and emissions of E22 on CO, CO2, HC, and $NO_X$ in the exhaust emissions from a production, 8-valve, and 4-stroke engine fuelled by hydrous ethanol (6.8% water content in ethanol). The engine was tested in a dynamometer and the results showed that torque and BMEP were higher when the gasoline-ethanol blend was used as fuel on low engine speeds. In their investigation at high engine speed, higher torque and BMEP were achieved when hydrous ethanol fuel was used. The use of hydrous ethanol caused higher power at high engine speeds, whereas for low engine speeds, both fuels produced about the same power. It was also observed that hydrous ethanol produced higher thermal efficiency and higher SFC than the gasoline-ethanol blend throughout all the engine speed range studied. On the exhaust emissions hydrous ethanol reduced CO and HC, but increased CO2 and $NO_X$ levels.

Turner (2011) investigated the effects of using different blending-ratios of ethanol and gasoline with respect to spark timing and injection strategies on a direct injection spark ignition engine at a part-load and speed operation. The result showed that adding ethanol into gasoline reduces engine emissions and increased efficiency, and the addition of ethanol modifies the evaporation properties of the fuel blend which increases the vapour pressure for low blends and reduces the heavy fractions for high blends.

Yao et al. (2013) investigated the effects E15 on a 2- and 4- stroke motorcycles using carburetor and fuel-injected engine mounted on a chassis dynamometer to measure the CO, UHC, and NOx emission. Their results showed that the CO from E15 decreased by 32% (carburetor) and 10% (fuel-injection). The UHC emissions also showed a reduction of 10% for fuel-injected engine, but no reduction was observed for the carburetor engine. No significant reduction of NOx emission was observed using E15.

Elfasakhany (2015) investigated the effects of performance and exhaust emissions from SI engine fueled with ethanol–methanol–gasoline blends. Ethanol–methanol blends (3–10 vol. %) in gasoline was compared to ethanol–gasoline blends, methanol–gasoline blends and pure gasoline. Results showed that when the engine was fueled with ethanol–methanol–gasoline blends, the concentrations of CO and UHC emissions were significantly reduced, this means that ethanol–gasoline blend provides the highest brake power.

Costagliola et al. (2016) investigated the effect of bioethanol–gasoline blends on the exhaust emissions and engine combustion of a 4-stroke motorcycle fuelled with E5 and E30 on chassis-dynamometer tests. They observed a significant reduction in carbon monoxide and particle number in using the ethanol gasoline blends.

Iodice et al. (2016) investigated the effect of ethanol/gasoline blends on CO and HC cold start emissions of four-stroke SI engines using E10, E20, and E30. The motorcycle was operated on the chassis dynamometer for exhaust emission measurements without any modification to the engine. Their experimental results shows that CO and HC cold start emissions decrease compared to the use of commercial gasoline, with the E20 ethanol blend achieving the highest emission reduction.

Ojapah et al, (2014) investigated the effects of E15 and E85 on both 4- and 2-Stroke controlled auto ignition (CAI) combustion processes with a range of load varied from 2.2bar to 8.6bar IMEP at 1500rpm. It was observed that E15 resulted in lower emissions of HC and NOx. The reduction of NOx was due to lower combustion temperature of E15, a higher ISCO emission was observed. The combustion efficiency was reduced as ethanol blend was increased to 85% resulting in the highest fuel consumption and CO emission.

Phuangwongtrakul et al. (2016) investigated the effects of various ethanol-gasoline blend E10, E20, E30, E40, E50, E60, E70, E85, and E100 using different engine speeds and varying percentages of intake-throttle opening at a fixed compression ratio. The lambda was maintained at stoichiometric and the ignition timing was tuned for maximum engine torque. The experimental results indicated that the ethanol-gasoline mixing ratio can enhance engine torque output, especially at low engine speed. The brake thermal efficiency was maximum when the engine was operated at 58-73% of WOT with an engine speed of 2000-2500 rpm, using E40 and E50 fuels.

Akansu et al. (2017) investigated the engine performance and emission values of gasoline, gasoline-ethanol and gasoline-ethanol-hydrogen blends, respectively and they observed that E20 resulted in poor engine performance and emissions. However, the engine performance and emission value were improved with the addition of hydrogen to the blend. The results showed that the addition of hydrogen to the gasoline-ethanol blend improved the combustion process and improved the combustion efficiency, expanded the combustion duration of the gasoline-ethanol blend, reduced emissions. But, nitrogen oxide emission values increased with the addition of hydrogen.

## The Experimental Set Up

### System Description

The set up for this experiment comprises of a 4-stroke single cylinder Maxi power engine generating set coupled to an electric power generator that was used to load the engine a unique Nanhua model NH4-506EN 5-gas analyzer, and set of loads in figure 1. The engine specifications is shown in table 1.

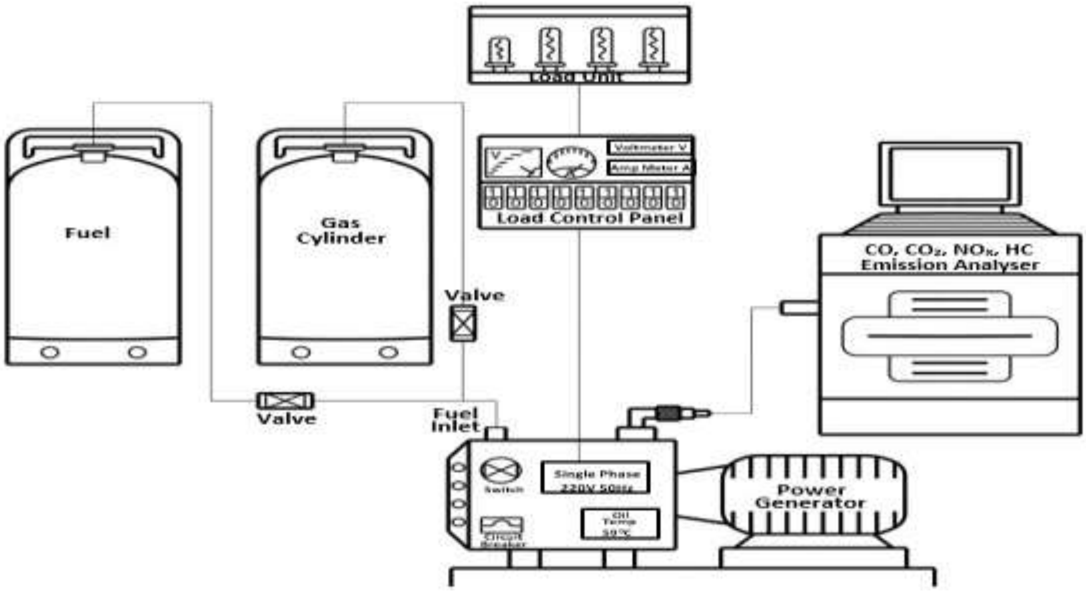


Figure 1: Overview of experimental setup

Table 1: General specification of test engine

| | |
|---|---|
| Model | E75 (M/K/KWH) |
| Displacement | 459cc |
| Rated frequency | 50Hz |
| Rated RPM | 3500rpm |
| Rated Voltage | 230V |
| Rated Amperage | 10.9A |
| Rated Power | 7.5KW |
| Max power | 8.0KW |
| Fuel tank capacity | 25L |
| Full load continuum running time | 6.0h |
| Exhaust gas analyzer | NH4-506EN Gas analyzer |
| Number of cylinder | 1 |

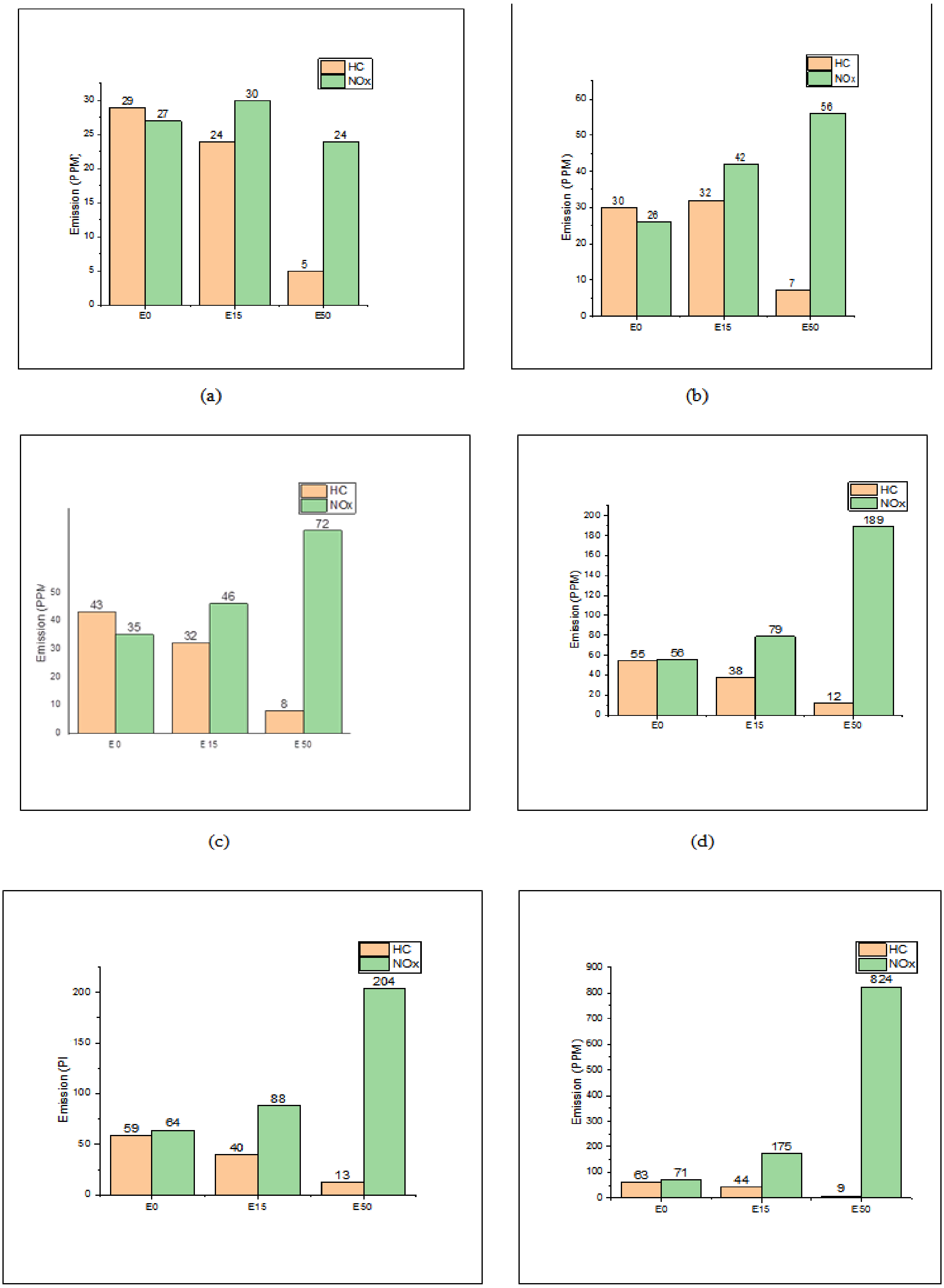
Table 2: Exhaust gas analyzer measurement range.

| Measured Quality | Measurement range |
|---|---|
| CO | 0… 10 (*$10^{-2}$) % |
| CO2 | 0… 18(*$10^{-2}$) % |
| O2 | 0….25(*$10^{-2}$) % |
| HC | 0… 10000 (*$10^{-6}$) ppm |
| NO | 0… 5000(*$10^{-6}$) ppm |
| RPM | 300rpm-8000rpm |

The exhaust gas analysis was performed using NH4-506EN Gas analyzer. A series of experiments were carried out under varying loads using E0, E15 and E50 blends. The load was varied from low to high, and the CO, UHC, $NO_X$ and CO2 emission of the various fuel blends were measured by the analyzer and recorded for further analysis and comparisons of the results. In addition, the value of lambda was noted for each engine operational load used. When using new blends the engine was operated for some time so that all residual fuel in the lines is used up before the readings are taken. The engine load used varies from idling or no load condition of, 0KW, 0.23kW, 1.34kW, 1.48kW, 2.6kW, 2.7kW and 4.6kW.

## II. RESULTS AND DISCUSSIONS

The emissions at different engine loads are shown in the bar chart below for HC and $NO_X$ emissions.



(a) (b)

(c) (d)

(e) (f)

Figure 2: Emissions of UHC and NOx for each blends in the loads used

In figure 2 (a-f), the UHC and NOx Emission using E0, E15 and E50 were observed for each loadings. In figure 2a for 0.23KW load, it was observed that UHC concentration for E0, E15 and E50 were 29PPM, 24PPM and 5PPM, respectively. The UHC concentration at E15 and E50 was decreased by 5 PPM and 24PPM respectively in comparison to E0 while NOx concentration for E0, E15 and E50 were 27PPM, 30 PPM and 24PPM, respectively. The NOx concentrations in using E15 increased by 3 PPM and that for E50 decreased by 3PPM in comparison to E0. This may be as a result of the charge cooling effect of the ethanol blend which may have resulted in reduced in-cylinder combustion temperature.

In figure 2b at a load of 1.34KW, it was observed that UHC concentration for E0, E15 and E50 were 30PPM, 32PPM and 7PPM, respectively. The UHC concentration at E15 was observed to increase by 2PPM and E50 decreased by 23PPM in comparison to E0. The NOx concentration for E0, E15 and E50 were 26PPM, 42PPM and 56PPM. The NOx concentrations in using E15 and E50 were increased by 16 PPM and 30PPM in comparison to E0.

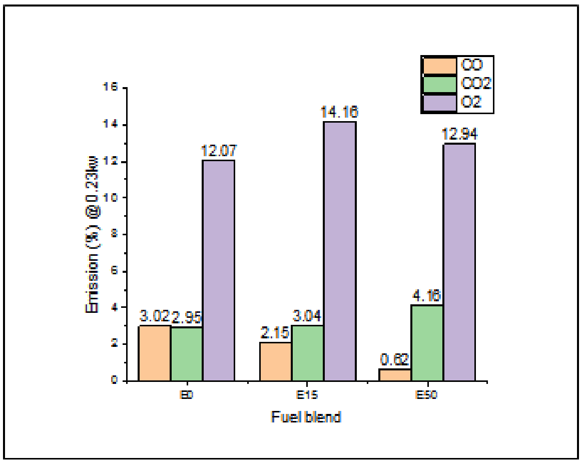
From figure 2c for a load of 1.48KW, it was observed that the UHC concentration for E0, E15 and E50 were 43PPM, 32PPM and 8PPM, respectively. The UHC concentration in E15 and E50 increased by 11PPM and 35PPM respectively in comparison to E0. The NOx concentration for E0, E15 and E50 were 35PPM, 46 PPM and 72PPM, respectively. The NOx concentration at E15 and E50 increased by 11PPM and 37PPM when compared to E0.

In figure 2d in using a load of 2.60KW, it was observed that the UHC concentration for E0, E15 and E50 were 56PPM, 38PPM and 12 PPM, respectively. The UHC concentration for E15 and E50 decreased by 18 PPM and 44PPM respectively compared to E0. The NOx concentration for E0, E15 and E50 were 56PPM, 79 PPM and 189 PPM. The NOx concentration of E15 and E50 increased by 23PPM and 133PPM in comparison to E0.

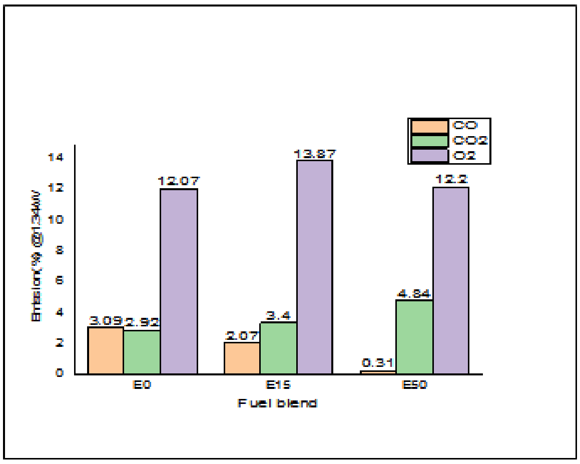
From figure 2e is for the load of 2.7KW, the UHC concentration for E0, E15 and E50 were 69PPM, 40 PPM and 13PPM, respectively. The UHC concentration of E15 and E50 decreased by 29 PPM and 56PPM compared to E0, the NOx emission values for E0, E15 and E50 were 64PPM, 88 PPM and 204PPM. The NOx emissions in using E15 and E50 increased by 24 PPM and 140 PPM compared to E0.

Figure 2f for 4.6KW load, which is the highest load used, for this load it was observed that the UHC concentration for E0, E15 and E50 were 63PPM, 44PPM and 9PPM. The UHC concentration at E15 and E50 decreased by 19PPM and 54PPM in comparison to E0, while the NOx emissions for E0, E15 and E50 were 71PPM, 175PPM and 824PPM. The NOx concentrations at E15 and E50 were increased by 104 PPM and 753 PPM in comparison to E0.

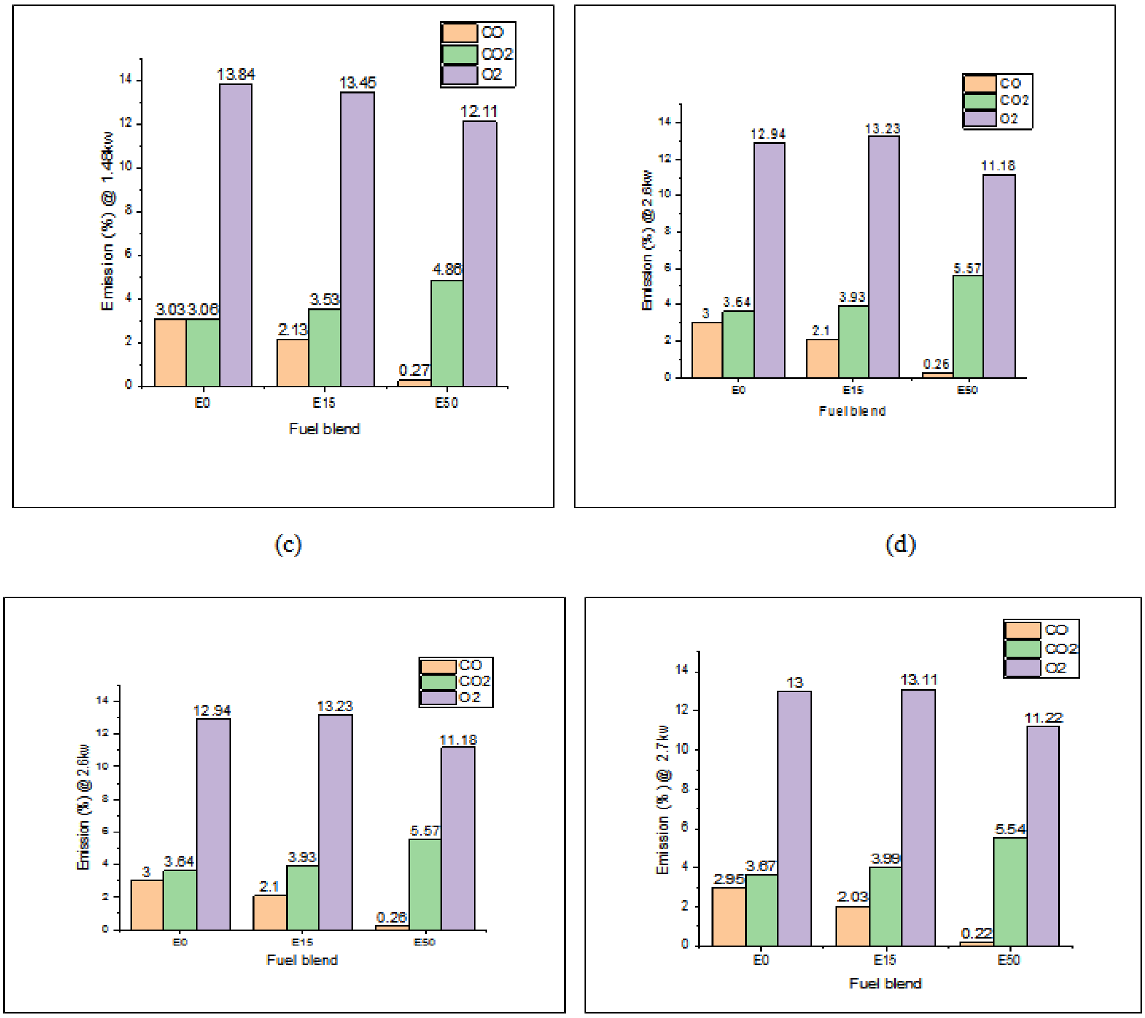
The emissions at different load for CO and CO2 and the corresponding measured O2 are displayed in figures 3(a-f).



(a)



(b)



(c) (d)

(e) (f)

Figure 3: Emissions of CO and CO2, and the corresponding O2 for the Blends

From figure 3a for 0.23KW load, it was observed that CO emission for E0, E15 and E50 were 3.02%, 2.15% and 0.62%. The CO concentrations at E15 and E50 was observed to decrease by 0.86% and 2.4% in comparison to E0, $CO_2$ concentration for E0, E15 and E50 were 2.95%, 3.04% and 4.16%. the percentage of this concentration at E15 and E50 increased by 0.09% and 1.21% over that of E0.

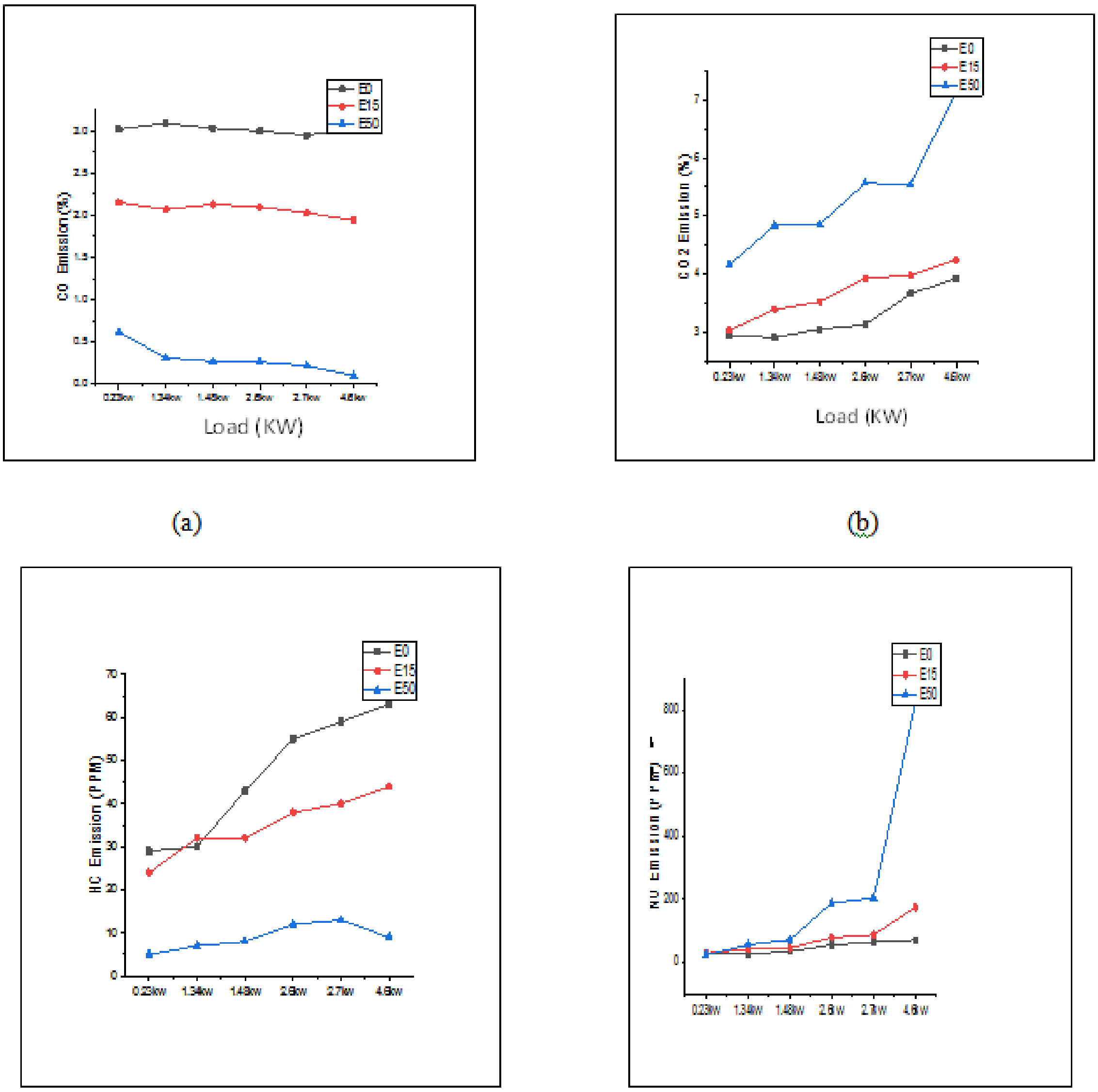
In figure 3b at 1.34KW load, it was observed that CO concentration for E0, E15 and E50 were 3.09 %, 2.07 % and 0.31 %, respectively. This emission of CO in using E15 and E50 decreased by 1.02% and 2.78% compared to E0, and the measured $CO_2$ concentration for E0, E15 and E50 were 2.92%, 3.4 % and 4.84%. The $CO_2$ emissions of E15 and E50 increased by 0.48% and 1.92% when compared to that of E0.

Figure 3c for the load of 1.48KW, the CO emission for E0, E15 and E50 were 3.03%, 2.13 % and 0.27%. The CO concentrations at E15 and E50 decreased by 0.9% and 2.76% compared to E0, and the $CO_2$ concentration for E0, E15 and E50 were 3.06 %, 3.53 % and 4.86 %. The $CO_2$ concentrations of E15 and E50 increased by 0.47% and 1.8% in comparison to E0.

Figure 3d is for 2.60KW load, the CO emission for E0, E15 and E50 blends were 3%, 2.1 % and 0.26%. This CO emission at E15 and E50 was decreased by 0.9% and 2.74% compared to E0, and $CO_2$ concentration for E0, E15 and E50 were 3.64%, 3.93 % and 5.57%, respectively. The $CO_2$ concentrations of E15 and E50 increased by 0.29% and 1.93% respectively in comparison to E0.

In figure 3e for 2.7KW load, the CO concentration for E0, E15 and E50 were 2.95%, 2.03 % and 0.22%, respectively. The CO concentrations of E15 and E50 decreased by 0.92% and 2.73% when compared to E0, the $CO_2$ emission for E0, E15 and E50 were 3.67%, 3.99 % and 5.54%. The $CO_2$ concentration for E15 and E50 blends increased by 0.32% and 1.87% respectively in comparison to E0.

The highest load of 4.6KW was used in figure 3f, the CO concentration for E0, E15 and E50 were 3.03%, 1.94 % and 0.1%. The concentrations of CO in using E15 and E50 blends decreased by 1.09% and 2.93% respectively compared to E0, the $CO_2$ concentration for E0, E15 and E50 were 3.93%, 4.35% and 7.14%. The $CO_2$ concentration in using E15 and E50 increased by 0.42% and 3.21% compared to E0.



(a)

(b)

(c)

(d)

Figure 4: Effects of increasing loads on emissions for the fuel blends

From the experiment carried out on the portable power generating production engine, we can conclude that E50 is more efficient with increasing load compared to E15 and E0. While CO reduces drastically as load increases, $CO_2$ increases as load is increased, the UHC decreases and NOx increases with increasing load. This can also be confirmed in figure 4(a-d), and agrees with the work from the literatures reviewed, the observe decrease in CO is due to the reduction in carbon atoms concentration in the blended fuel and the high molecular diffusivity and high flammability limits which improve mixing process and hence combustion efficiency. The $CO_2$ increases as additional load is added to the engine, this is because when ethanol containing oxygen is mixed with gasoline, the combustion of the engine becomes better. The $NO_x$ increases as the load increases, this can be as a result of increase in the quantity of fuel inducted into the engine must have lead to an increase in combustion temperature resulting in NOx increase.

## III. CONCLUSION AND RECOMMENDATIONS

1. Ethanol increases the engine performance by increasing volumetric efficiency, thermal efficiency but specific fuel consumption increases because ethanol has less calorific value as compared to gasoline.
2. From the experiment conducted, it was that E50 have better effect on the engine as it reduces the emission and improves the performance of the engine compared to E15 and E0. But in this work for the fact that the ethanol will be obtained locally, it will create another avenue for revenue generation as well improving the local economy.
3. Ethanol has added advantage of being a relatively sustainable energy source and can be made locally, the effect of long term usage on engine life was not considered, but there is vast literature on this and how to mitigate it.
4. More attention will be needed to be focused on alternatives fuel blending such as tri-blending other than blending with gasoline alone such as ethanol-methanol-gasoline (GEM). Though ethanol has a high latent heat of vaporization and corrosive effect over metal and plastic, we should avoid using pure ethanol alone, as it is not suitable for SI engines since the current production power generating engine are not designed for flexible fuel. In addition, pure or neat ethanol usage may not be economically feasible. But low to moderate percentages blending can have significant impact on emission reductions and improve the local economy

**Acknowledgements**

We would like to acknowledge the support of the **Royal Academy of Engineering UK** through the **HEPSSA 1_5** project in procuring the research engine and the emission analyzer used in this project.

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