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THE EFFECT OF SPARK-PLUG LOCATION ON NO_x AND VOC EMISSIONS IN A SINGLE CYLINDER TWO-STORE SI ENGINE USING BLEND FUEL

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ABSTRACT

This study was conducted to determine the effect of changing spark-plug location on NOx and VOC (Volatile Organic Carbon) emissions in a single cylinder two-stroke spark ignition engine using ethanol-gasoline blend as fuel at different ratios. Two possible positions of spark-plug were considered: X = 0 (Original position of spark-plug) and x = 1.6 10^{-1} mm position slightly away from turbulent area. The results obtained shows that there is a clear trend of reducing NOx and VOC emissions with increasing ethanol content. The NOx emission concentration increases from 0 - 20% ethanol content by volume at position x = 0 from start of combustion and decreases as ethanol content increases for the same position of x = 0.

For position, x = 1.6 x 10^{-1} mm spark plug position slightly away from turbulent area NO_x emission show the same characteristics from start of combustion except for NO, and NO_2 which show a steady increase from start of combustion to a ratio of 40G: 60E ethanol-gasoline content.

The emission level further decreases in both cases and assume a slight increase for ethanol content above 40%. The increase in No, NO_2 and VOC emissions at a ratio of 60G: 40E ethanol gasoline content by volume for position, x = 1.6 X 10^{-1}mm is due to increase in lead-time and change in the stoichiometric air/fuel ratio, leading to incomplete combustion, increase combustion temperature and excessive pressure inbult in the combustion chamber.

KEYWORDS: Lead-time, Ethanol-Gasoline blend, SI Engine, Emission Concentration

INTRODUCTION

Spartk-plug thread sitting on the cylinder block is normally rethreaded by local mechanic during worn-out situation, basically for economic reasons of saving cost of replacing a new cylinder block. This practice is common with the Asian motorcycles used for commercial purposes all over Nigeria. The original position is normally altered during rethreading. This slight adjustment affects the engine performance and consequently constitutes a detrimental effect to air quality. It is on this premise this research work was carried out to investigate the effect of this slight variation in spark-plug location to NOx and VOC emissions.

In recent years research and development work has been geared to making a better fuel combustion and reduce noise and pollutant emissions by carrying out simulation that will lead to design of combustion chambers and locating position of spark-plug for better combustion efficiency. (Chin et al 1992; Fiveland and Assanis 2001).

The effect of spark-plug location on NOx and VOC emissions may be related to a number of engine processes due to increase in lead-time (Amoo 2000). These processes include: Instantaneous gas temperature that first increase and then decreases, high gas pressure and possible increased turbulence which may lead to detonation and reduction in work transfer to the piston. These factors affect cylinder heat transfer, burn rates, combustion stability and flame quenching, which in turn affect NOx and VOC emission concentration.

The effect of adding ethanol is to oxygenate the fuel as depicted in Gurrei (1998). The higher the ethanol blend, the higher the fuel oxygenation. The increase oxygen in the fuel changes the stoichiometric air/fuel ratio of the fuel, and provides the minimum amount of oxygen needed for the complete conversion of all the fuel into oxidized product, hence reducing toxic emissions (Sapre, 1986; Liu and Bian 2005).

NOx formation mechanism

NO and NO_2 are normally grouped together as NOx emissions. NO is the predominant oxide produced inside the engine cylinder. Four major mechanisms have been proposed for the formation of NO in combustion processes, thermal, prompt, nitrous oxide and fuel nitrogen.

In general, the thermal mechanism is considered to dominate the production of NO for conventional engines (Heywood 1988). The production of NO from combustion in air is assumed to be determined by the extended Zeldovich mechanism (Lavoier and Heywood 1970).

$$N + O2 \leftrightarrow NO + O \quad (1)$$
$$O + N2 \leftrightarrow NO + N \quad (2)$$
$$OH + N \leftrightarrow NO + H \quad (3)$$

Equations (1) and (2) are the original Zeldovich; while equation (3) is less important added by Lavoie. The concentration of N_2, O, OH and H may be assumed equal to the instantaneous values. The nitrogen atoms (N) exist at low concentrations (~ $10^{-0.7}$ gmol/cm^3) and a steady state approximation is valid for these species (Heywood 1998). These reactions are known as thermal NO rate since the strong triple bond of the N_2 molecule can only break apart at relatively high temperatures. The experiment was carried out on a single cylinder two-stroke SI engine using gasoline-ethanol blend with the aim of arriving at a better understanding of the engine performance at these spark-plug locations, observed the emission concentration at same points to assist in future design of the most tolerable blend mixture and position of spark-plug for optimum performance.

Material and methods

(i) Engine Specification

The test engine used for this study is a single cylinder two-stroke SI engine. The design specifications were not altered during the course of this experiment. Specifications are shown in table 1.0.

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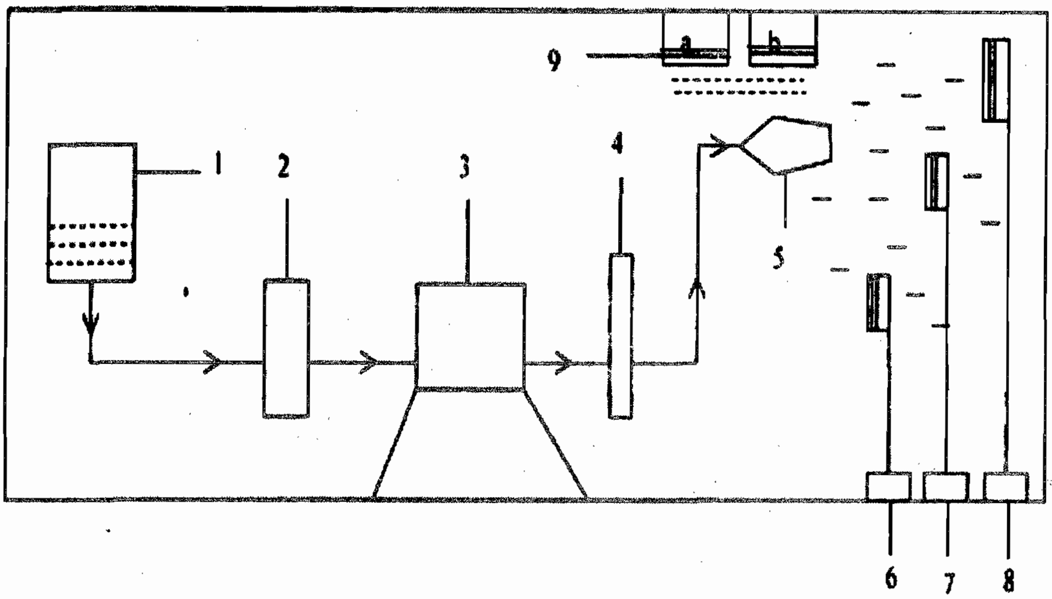
Table 1.0: Test Engine specifications.

Specification	Test Engine
Type	2-stroke air cooled SI petrol Engine inclined at 25°
Bore	60mm
Stroke	42mm
Compression ratio	8:1
Displacement	118m1
Maximum Torque	0.75/2800kg-m/rpm
Valve train	2 valve per cylinder
Spark-plug	Recessed gap single electrode

(iii) NOx and VOC determination.

The VOC and NOx emission where determine for the two spark-plug locations x = 0 (Original position of spark-plug) and x = 1.6 x 10^{-1}mm, position slightly away from turbulent area.

Portable gas detector monitors with temperature range of -10 to 120°C and humidity range of 0 – 90% RH, non condensing were used for the automatic determination of the ambient concentration of NO, NO_2 N_2O and VOC placed some distance away from the test engine hung on stand in the direction of the exhaust stack and first calibrated under pure condition made possible by base laminar flow head. Each detector was made to identify a particular type of gas. The emission concentrations were determined at each position of spark-plug and blend ratio of ethanol content by volume. The exhaust emission temperature was determined by a K type thermocoupe placed at the emission line. Results were tabulated for the two cases of spark-plug positions. The schematic line diagram for the experimental set up is shown in figure 1.



1. Tank, 2 – Carburetor; 3 – Engine, 4 – Thermometer; 5 – Divergent nozzle. 6 – NO detector;
2. 7 – NO_2 detector; 8 – N_2O detector; 9 – a, b –Respirable Cartridge for particulate trap.

Fig. 1: Line diagram of experimental set up

RESULT AND DISCUSSION

Figure 2 and 3 show the effect of burning ethanol-gasoline blend at different blend ratios on NO, NO_2 and N_2O emissions in ppm. From figure 2 addition of 20% ethanol content by volume lead to increase in the three emissions, but decreases at 40% ethanol content. The emission concentration increases slightly above 40%, showing that above 40% ethanol content equivalent to a ratio of 60G: 40E ethanol content by volume the system cannot always maintain a stoichiometric air/fuel ratio to completely oxidize the combustion products. Furrey (1985).

The results in figure 3 for x = 1.6 x 10^{-1}mm show the same trend except for the increase in emission level of NO and NO_2 from start of combustion. The reason for this increase is due to increase in lead-time leading to incomplete combustion. Figure 4 show the trend of VOC emission represented by methane for the two cases. The VOC in the two cases show a similar pattern in their combustion behavior with ethanol increase. But for the second case of spark-plug variation the emission concentration is noticed to have increased with higher emission values than the first case caused by increase in the distance of the spark travel leading to late combustion state. However, both cases show a decrease in emission level for blend fuel.

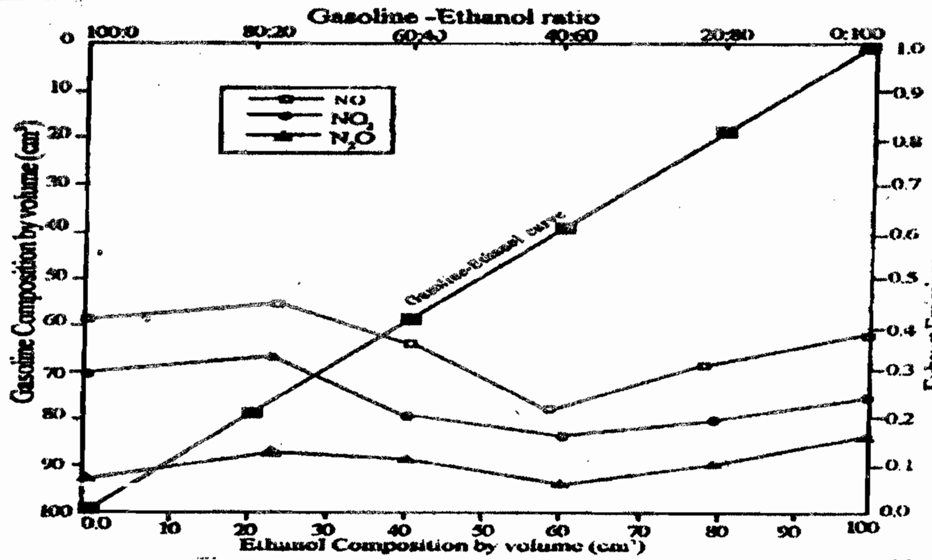


Figure 2.0: The effect of blend fuel on NO, NO_2 and N_2O emissions for spark-plug position x = 0

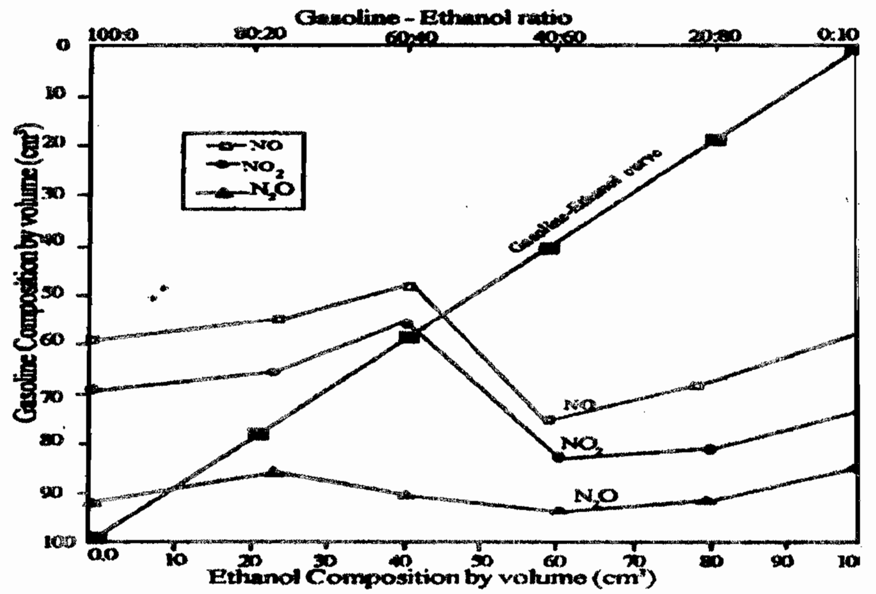


Figure 3: The effect of blend fuel on NO, NO_2 and N_2O emissions for spark plug position x = 0 16mm.

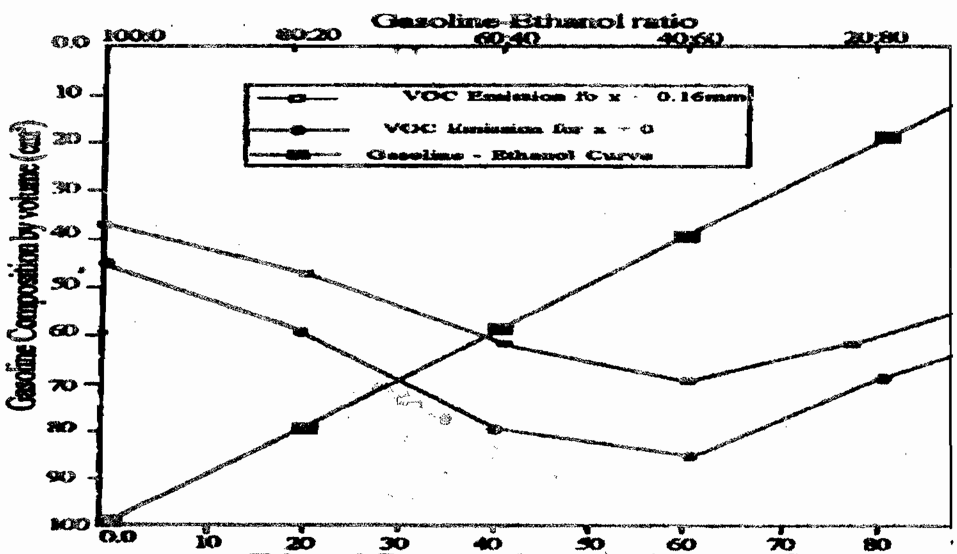


Fig. 4: Volatile organic carbon emission(VOC) for differe blend ratios at spark-plug positions x = 0 and x =0.16m

CONCLUSION

The experimental investigation conducted in this work indicates that spark-plug position play a contributive role to affecting emission characteristics. Spark-plug location too far from area of turbulence lead to about 8 – 10% increase in emission level as observed in this study. The use of blend fuel can lead to 30 – 35% reduction of exhaust emission, thus reducing environmental impact. The study therefore recommends 30% ethanol blend be used and centrally located spark-plug position can reduce lead-time and enhance combustion efficiency.

Nomenclature

NOx	Oxides of nitrogen (NO, NO_2 N_2O)
NO	Nitrogen (I) oxide
N_2O	Nitrogen (II) oxide
NO_2	Nitrogen (IV) oxide
SI	Spark ignition
ppm	parts per million
VOC	Volatile Organic carbon
E:G	Ethanol –Gasoline blend

REFERENCES

Amoo, H. R. 2000. Study of fractal burning model and the effect of spark-plug position in spark-ignition engines. M. Sc. Thesis, faculty of engineering, Ferdosi University of Mashhad unpublished.

Chin, Y. W. Matthews, R. D, Nicholas, S. P., Kiehne, T. M., 1992. Use of fractal geometry to Model turbulent combustion in SI engines, Combustion science and Technology pp. 1- 30.

Fiveland, S. B. and Assanis, D. N., 2001. Development of a two-zone HCCI Combustion Modal accounting for boundary layer effects, SAE 2001 – 01 – 1028.

Furrey, R. L. and Marvin, W. J., 1985. Exhaust and evaporative emission from a Brazilian Chevrolet fuelled with ethanol-gasoline blend. SAE 2001 – 790281.

Guerrie, D. A ., 1998. Investigation into the vehicle exhaust emission of high ethanol Blends SAE950777.

Sapre, A. R., 1998. Performance and emissions of medium concentrarion of Methanol-Gasoline blends in a single cylinder spark-ignition Engine. SAE paper 881679.

Heywood, J. B. and Lavoie, G. A. 1970. Experimental and theoretical study of nitric oxide formation in internal combustion engines. Combustion science Technology. P313 – 338.

Heywood, J. B., Higgins, J. M., Watts, P. A., Tabczynski, R. J. 1979. Development and use of cycle simulation to predict SI engine efficiency and NOx emissions SAE paper 790291.

Heywood, J. B. 1988. Internal Combustion Engines Fundamentals, McGraw-Hill, New York.

Liu, J. C. and Bian, Y. Z., 2005. Properties performance and emissions of Methanol-Gasoline blends in spark ignition engines, proceedings of the IMECH E, part D Journal of Automobile Engineering number D3 PP405 – 412.

Miller, J. A., Brown, C. T. 1989. Mechanical and Modelling of Nitrogen Chemistry Combustion. Energy Combustion Science, pp.287 – 338.