An Experimental Investigation of The Performance Indicators of Gasoline Engine with Octane Number Additive

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Abstract:- This study analyses the impact of a commercial octane number additive on the performance metrics of a spark-ignition engine in addition to measuring gas emissions. The effective conditions with the lowest gas emissions are investigated using five different volumes of octane number additive to local fuel ranging from 100 to 400 ml, and ten different engine speeds ranging from 1000 to 5500 rpm. It is looked at how well the gasoline engine performs in terms of torque, braking force, fuel consumption particular to the brakes, and the emissions of CO, CO_2, N_2O, and un-burned hydrocarbon. The results indicate that adding a commercial octane number additive to the local fuel has increased engine performance indicators and simultaneously decreased gas emissions. To guarantee the highest performance indicators of the gasoline engine and the minimal level of exhaust gasses, a certain volume of octane number additive and speed engine should be used.

***Keywords*:-** *Fuels, Commercial Octane Number Additive; Spark-Ignition Engine Performance, Exhaust Emissions, Exhaust Gases.*

I. INTRODUCTION

Gasoline engine is a type of internal combustion engines that widely used in transport vehicles engines, motorcycles, and generators. Undoubtedly, the modern vehicle engines require the use of high-quality fuels to obtain high efficiency and low exhaust gases emissions. In this regard, the fuel enhancers are produced to raise the fuel octane numbers. Evaluating engine performance variables such as torque, brake power, brake specific fuel consumption, and brake thermal efficiency, as well as emissions percentage, is an important step in determining the effectiveness of fuel additives. In this field, several studies were focused on enhancing the engine's performance via deploying fuel enhancers. For instance, Thangavelu et al. (2016) studied the influence of of bioethanol additive to the gasoline fuel on the performance of the spark-ignition engine with a simple comparison against the gasoline fuel. The results showed that the Bioethanol additive has lowered the gases emissions. However, and increase of fuel consumption at lower power is deduced. Yusri et al. (2017) assessed the use of a secondary butyl alcohol –gasoline mixture with a volume ratio of 5% on the exhaust pollution emission of a four-stroke spark-ignition engine. The characteristics of exhaust emissions were compared to the characteristics of exhaust emissions of the engine with gasoline fuels (G100) as a reference fuel. Specifically, the result showed that engine with butyl alcohol –gasoline mixture fuel has produced lower CO and HC, but higher CO2. Deng et al. (2018) studied experimentally the exhaust noise, performance, and emission characteristics of a gasoline engine fueled by a mixture of gasoline and volume ratios of 10%, and 20% of hydrous ethanol (E10W and E20W, respectively) with a comparison against the pure gasoline (E0). The results showed that E10W and E20W produced much lower exhaust noise along with low engine speeds compared to EO. However, an increase of the engine speed delivers an advantage of E0 that showed a lower exhaust noise. Also, hydrous ethanol-gasoline was capable of realizing comparable torque and power compared to E0 at all operating conditions, which in turn confirmed the prosperity of hydrous ethanol-gasoline as a promising alternative for SI engines**.** However, the engine fuelled with three fuels displayed comparable noise emissions at high speed.

Hadi et al. (2020) studied the enhancement of gasoline fuel quality by mixing it with commercial fuel additives. The engine's performance was evaluated based on different fuel properties. Specifically, local gasoline fuel was mixed with two types of commercial fuel optimizer and tested in a single-cylinder engine. The study ascertained an increase in the viscosity of fuel mixtures MU1, MU2 by ratio 3.49% and 16.92%, respectively, that entailed as increase in octane number (fuel quality) and an enhancement of thermal efficiency by about 22.4%.

Based on the above studies, it can be stated that the fuel consumption and air pollution are becoming major problems in the world that attracted the attention of several colleagues. The interest is continually increased to enhance the performance of gasoline engine via retarding the gases emissions and air pollution to maintain a greener environment. Recently, a large number of commercial octane additives for spark-ignition engine fuels are presented in the markets. Up to the authors' knowledge, a thorough evaluation of adding octane number additive on the performance of spark-ignition engine has not been conducted yet. Thus, this study aims to experimentally investigate the influence of adding an octane number additive of different volumes to fuel on the performance indicators of a gasoline spark-ignition engine. In this regard, several performance indicators will be tested including the torque, measurement of brake power (B.P.), brake specific fuel consumption (BSFC), and the concentration of emissions (CO_2, CO, HC, and NOx).

II. EXPERIMENTAL WORK

➢ *Description of the Gasoline Engine*

An internal combustion engine (Manufacturer: Daewoo, South Korean automotive company) of four cylinders and four strokes works by gasoline fuel using a fuel injection system is used in this study. The engine is connected to an electrical dynamometer installed on a strong stage as shown in Fig. 1. The dynamometer consists of consists of several instruments including the gauge board with rotational velocity (rpm), a torque sensor, fuel consumption meter, air flowrate meter, and sensor of water temperature. The specifications of the selected engine are provided in Table 1. The exhaust gases emissions were measured using an exhaust digital gas analyzer that successfully measured the concentration of (CO_2, CO, HC, and NOx). To experimentally specify the performance of the internal combustion engine using different types of fuels within a set of variable speeds ranging between 1000 to 5500 rpm, constant compression ratio (r) and a full open throttle valve, six different models of fuels were prepared including the pure gasoline fuel (60 L) and a commercial octane number additive added to a gasoline fuel (60 L) at specific proportions of 100 ml, 150 ml, 300 ml, 350 ml, and 400 ml. Table 2 depicts the characteristics of the local gasoline fuel.

Fig 1 Engine with Equipment

Table 1 Specification of the Selected Engine

No	Make	
1	Manufacturer	Daewoo, South Korean automotive company
2	Type	Four-cylinder
3	Number of cylinders	4
4	Max. Power	81 kW
5	Fuel injection timing	Multi-Point indirect injection
6	Bore ×Stroke	86 mm × 86 mm
7	Compression ratio	8.8:1
8	Engine displacement	1998 cm^3
9	Engine cooling fluid	Water

Table 2 Characteristics of Local Gasoline Fuel

Fuel properties	Local gasoline fuel
Density (15 C°)	0.79
Low heat value (kJ/kg)	44150
Latent heat of vaporization (kJ/kg)	349
Kinematic viscosity (40 °C)	0.6
Stoichiometric air-fuel ratio	14.7

➢ *Preparation of Fuel Samples*

To conduct practical experiments, six different fuel samples were prepared, base gasoline was mixed with octane number additive from 100 to 400 ml to get test mixtures. The mixture was stirred well to ensure that fuel mixture homogeneous. The octane number of the mixture increased with the increase in the amount of additive, and the increase reached 4 degrees, Table 3 shows the fuel mixture properties.

Table 3 Properties of Fuel Mixture (Fuel Models)

Property item	Gasoline	100m	150mL	300mL	350mL	400mL
Density (g/cm^3	0.791	0.7713	0.7744	0.7765	0.778	0.7789
LHV (KJ/Kg)	44150	43412	43150	42970	42611	42266
RVP (Kpa)	60.1	84.2	84.38	84.2	84.2	84
MON	85.4	87.8	88.2	89	89.6	89.8
RON	91.8	93.2	94.1	94.9	95.2	96.1
Anti - Knock	84.45	86.55	87.2	87.6	87.7	87.8
Oxygen (g/cm^3)	0	1.94	2.84	3.92	4.68	5.94

The octane number of the mixture has increased as a result to increasing the volume added of octane number additive as shown in Fig 2.

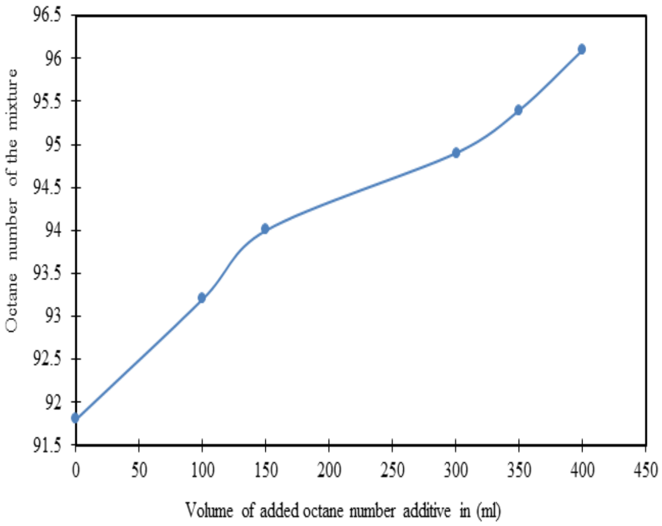

Fig 2 The Change of Octane Number of the Mixture with Octane Number Enhancement

III. MATHEMATICAL MODELING

The performance of the internal combustion engine was estimated based on the model equations of Kaisanet al. (2020) as described below;

- *Brake power (BP): Brake power is the amount of power delivered to the engine's output shaft. It is measured using a dynamometer and is a key performance variable that determines the engine's overall power output. Brake power can also be measured at different engine speeds and load conditions to evaluate the effect of fuel additives*

$$BP = \frac{2\pi\, N\, T}{60} \qquad (1)$$

N and T are the revolution per minute and Torque, respectively.

- *Brake thermal Efficiency (η_{BTE}): Brake thermal efficiency is a measure of how well the engine converts fuel energy into useful work. It is calculated as the ratio of brake power to fuel energy input. A higher η_{BTE} indicates better engine efficiency. To evaluate the effect of fuel additives on η_{BTE}, the engine can be operated at different speeds and loads, and the fuel consumption and power output can be measured. Accordingly, η_{BTE} is the ratio of the output brake power to the input chemical energy from the fuel supply,*

$$\eta_{Bth} = \frac{BP}{m_f\, C.V} \qquad (2)$$

m_f and $C.V$ are mass flowrate of gasoline, specific heat at constant volume, respectively.

- *Brake specific fuel consumption (BSFC):*

BSFC is the amount of fuel consumed per unit of power output. It is a measure of engine efficiency and is calculated as the ratio of fuel consumption to brake power. A lower BSFC indicates better fuel efficiency. To evaluate the effect of fuel additives on BSFC, the engine can be operated at different speeds and loads, and the fuel consumption and power output can be measured. Accordingly, BSFC is mathematically represents the ratio of mass of fuel (m_f) to the output brake power,

$$BSFC = \frac{m_f}{BP} \qquad (3)$$

- *Exhaust Gases Emissions.*

Fuel additives can have an impact on engine emissions, including carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and particulate matter (PM). To evaluate the effect of fuel additives on emissions, the engine can be operated under controlled conditions, and the exhaust gases can be analyzed using an emissions analyzer. The emissions data can be compared with and without the use of the fuel additives. The digital device is used to measure the percentage of the exhaust gases including the carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO, NO_2), hydrocarbons (HC).

IV. RESULTS AND DISCUSSION

This section illustrates the results of the experiments and associated discussion that identify the performance indicators of an internal combustion engine based on the utilisation of octane number enhancement to fuel under variable speed engine. This in turn would help to identify the influence of octane number additive on the torque, brake power, brake specific fuel consumption, and the gases emissions for a wide set of engine speed.

The pressure from the cylinder pushing against the piston during the power stroke causes the engine to produce torque on the crankshaft. Your car's speed is determined by both horsepower and torque. The amount of twisting force that something can produce is referred to as its torque. Fig. 3 shows the relationship between the torque of engine (measured in N.m.) and the added volume of octane number additive, ranges between 100 to 400 ml, for different engine speed measured by the rotation per minute (RPM). Clearly, there is a fluctuated behavior of torque against the added volume of octane number additive to the local fuel. An increase of torque can be seen due to adding the additive to the local fuel. Thus, it can be stated that adding octane number enhancement to fuel has a positive contribution to torque. More importantly, the highest torque can be achieved using either 150 ml or 350 ml of octane number additive to the local gasoline fuel with the superiority of 350 ml to gain the optimal torque for the applied range of engine speed between 1000 to 5500 rpm. However, it is not recommended to add more than 350 ml of octane number additive due to a clear decrease of torque.

Fig. 3 also shows that the implication of 4500 and 5000 rpm is important to maximise the Torque with the preference of using 5000 rpm as an optimal value of engine speed.

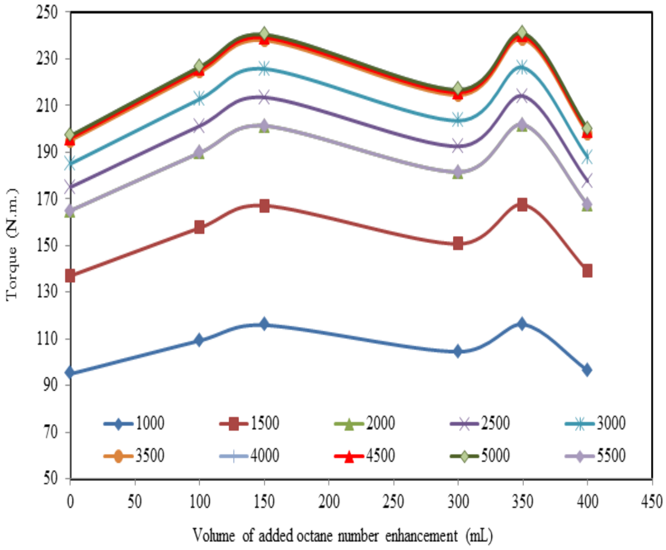

Fig 3 Torque Against Volume of Added Octane Additive for Variable Speed Engine

Fig. 4 shows the relationship between the brake power (B.P.) measured in kW and the added volume of octane number additive for different engine speed (rpm) for all fuel models. In the slow speed range, there is insignificant increase in brake power of the engine due to increasing the added volume of additive. However, a significant fluctuation of the brake power can be noticed after increasing the speed engine beyond 3000 ppm. In this regard, the utilisation of 5000 rpm at 150 and 350 ml of octane number additive would guarantee the maximum brake power. The results of Fig. 4 corroborate the results of Fig. 3 that identified the maximum torque within the same conditions. Seemingly, a complete combustion was happened at the optimal conditions obtained in Figs. 3 and 4 that associate the maximum heat released.

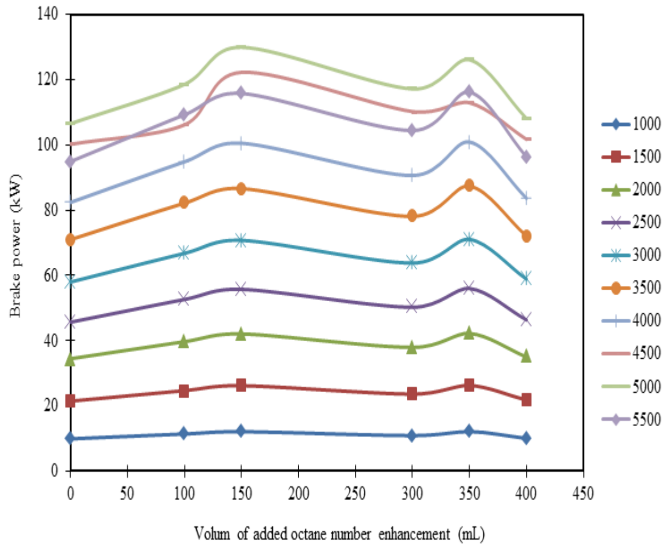

Fig 4 The brake power against added volume of octane additive for variable speed engine

The specific fuel consumption (BSFC) measured in (g/kW hr) is an indication of the amount of fuel consumed by a vehicle for each unit of power output. Thus, the lower the engine with the BSFC, the more efficient is the engine. The influence of adding octane number additive at different volumes on the BSFC of the gasoline engine at different speed engine between 1000 rpm to 5500 rpm is represented in Fig. 5. Clearly, it is fair to admit the sensitivity of the BSFC against the added volume of octane number additive. Fig. 5 shows a positive influence of octane number additive at 150 ml that shows the maximum reduction of the BSFC. However, this is not the case beyond 150 ml where a continuous increase in the BSFC can be seen which finally ascertains the highest BSFC at 400 ml of added volume of octane number additive. Thus, the results of Fig. 5 recommend to not add more than 350 ml of octane number additive due to increasing the rate of fuel consumption. however, Fig. 5 affirms the importance of increasing the speed engine to assure the lowest fuel consumption where the 5000 rpm has got the lowest values. Hadi et al. (2020) affirmed this fact where the increase in the speed of flame spread through the air-fuel mixture inside the combustion chamber can lead to the disappearance of the knocking sounds of the engine.

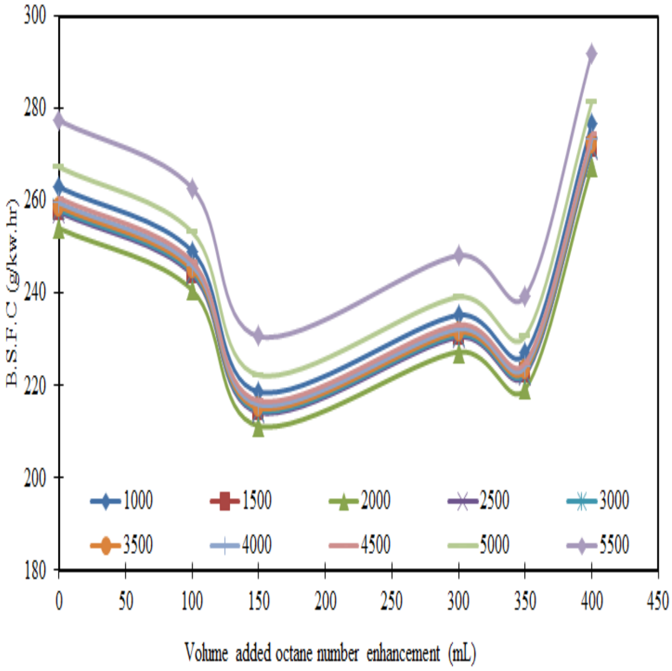

Fig 5 The BSFC Against Added Volume of Octane Additive for Variable Speed Engine

The brake thermal efficiency of the gasoline engine has also been calculated in this study. Fig. 6 represents the change in the brake thermal efficiency due to increasing the added volume of octane number additive for a range of gasoline speed engine between 1000 to 5500 rpm. Apparently, the utilisation of 150 ml of octane number additive has got the maximum brake thermal efficiency compared to all other added volumes. In this regard, Fig. 6 shows the improvement of brake thermal efficiency as a result to increasing the speed engine to 5000 rpm.

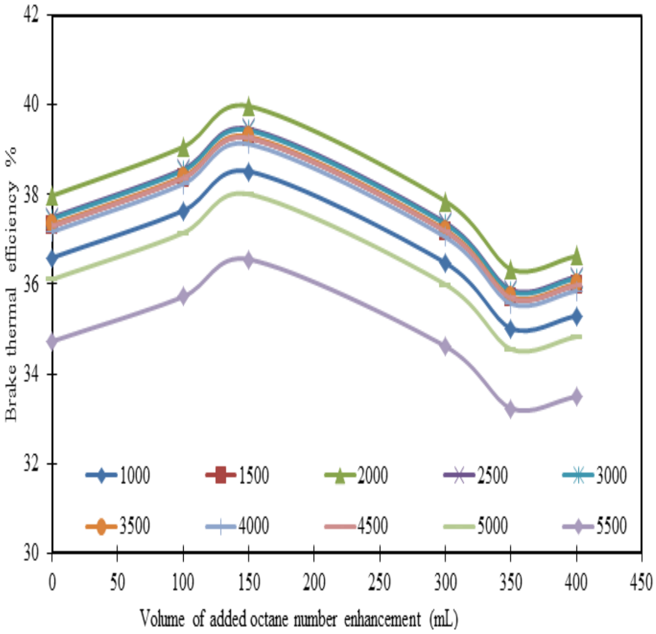

Fig 6 The Brake Thermal Efficiency Against Added Volume of Octane Additive for Variable Speed Engine

Overall, Figs 3 – 7 shows the significance of using octane number additive due to its capacity to promote the performance indicators of the gasoline engine.

Automotive Exhaust Gas Analyzers are typically employed to identify and resolve issues with engine emissions and to enhance engine performance. Gas analyzers assist with emission compliance and immediately give trustworthy results. They are employed to estimate the levels of gases such as carbon monoxide. The analysis of exhaust gases was carried out by using an electronic exhaust gas analysis system (Digital system). Fig. 7 shows how the addition of the octane number boost significantly reduces CO_2 emissions. The lowest CO_2 was specifically attained after 350 ml of octane number additive. Despite the engine with the lowest applied speed (1000 ppm) has produced the lowest CO_2 percentage, this is not the optimum conditions. The speed engine of 3500 ppm will be selected as the best speed engine due to considering the associated emission of CO (presented in Fig. 8). In this regard, it is reasonable to anticipate that the emission of carbon monoxide would be the inverse of the emission of CO_2. Fig. 8 represents the change in carbon monoxide CO ratio with increasing the added volume of octane number additive for variable speed engine. A significant reduction of CO can be noticed after adding 350 ml of octane number additive. More importantly, the speed engine that introduces the highest rate of CO_2 has simultaneously produced the lowest rate of CO. This would therefore highlight the significance of applying 350 ml of the additive at the 3500 ppm of engine speed to ensure the lowest CO emission. This is comparable with using the lowest speed engine of 1000 rpm that introduces the maximum discharge of CO, which has a vital negative influence on the ecosystem.

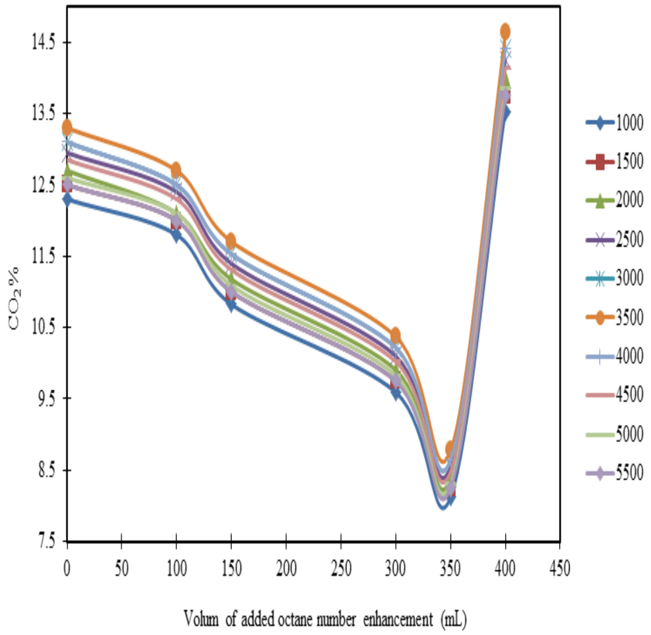

Fig 7 The Ratio of CO_2 from Exhaust Gases of the Gasoline Engine Against the Added Volume of Octane Additive for Variable Speed Engine

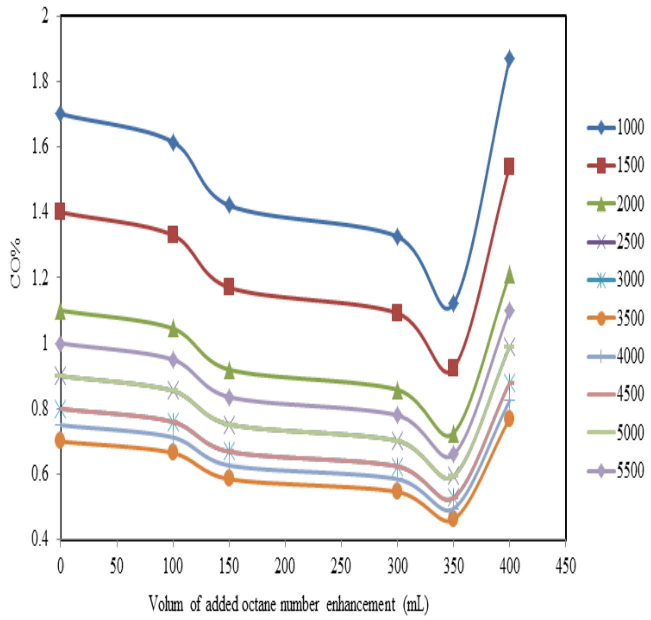

Fig 8 Carbon Monoxide (CO) Emissions from Exhaust Gases Against the Added Volume of Octane Additive for Variable Speed Engine

The associated emissions of Nitrogen Oxides (NO, NO_2) denoted as N_{OX} measured in ppm is represented in Fig. 9. Fig. 9 shows the importance of adding octane number additive to reduce the N_{OX} emission especially with the utilisation of a high speed engine. Fig. 9 also ascertains the lowest N_{OX} emission with the addition of 350 ml of octane number additive. These results corroborate the results of Figs. 6 and 7. Also, the highest reduction of N_{Ox} emission can be carried out at the lowest speed engine of 1000 rpm.

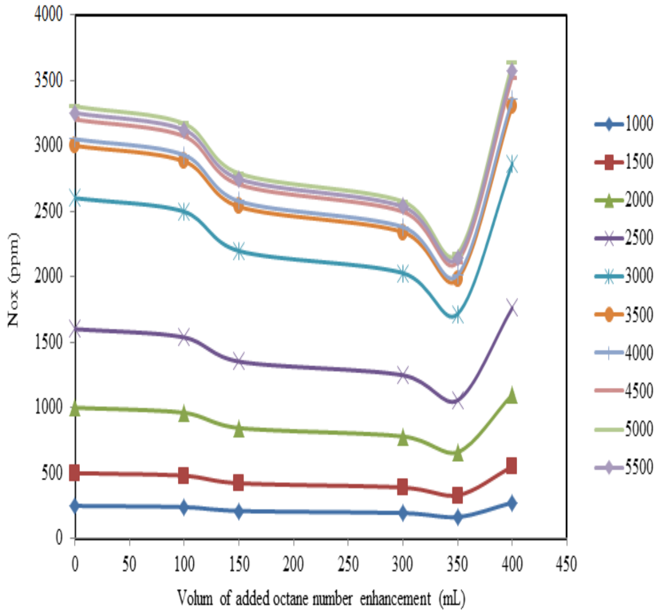

Fig 9 Oxides of Nitrogen (NO, NO_2) Emissions from Exhaust Gases Against the Added Volume of Octane Additive for Variable Speed Engine

The emission of unburned hydrocarbons (HC) as a result of applying octane number additive of various amounts while taking into account variable engine speeds is shown in Fig. 10. Indeed, adding the octane number additive has a positive influence on reducing the emission of HC gases. This can be seen clearly after using a high speed engine. In fact, 350 ml of octane number additive has resulted in the lowest HC emission. The impact of octane number additive on the lowest speed engine appears to be more obvious than on the highest speed engine. Also, the utilisation of the 3500 rpm of speed engine has obtained the lowest emission of HC. Thus, the results of Fig. 10 would confirm the usefulness of 350 ml of octane number additive and 3500 rpm of speed engine.

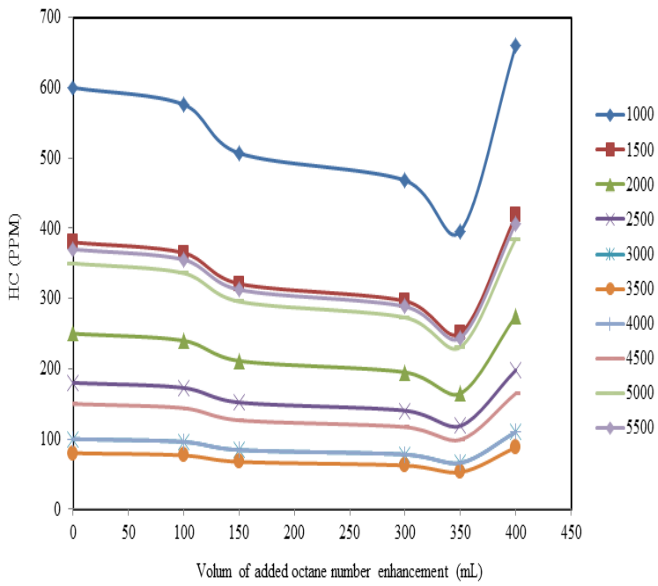

Fig 10 Unburnt Hydrocarbon (HC) Emissions from Exhaust Gases of an Engine Against the Added Volume of Octane Additive for Variable Speed Engine

Finally, Figs. 8–10 highlight the significance of avoiding the use of 400 ml of octane number addition because doing so would result in higher gas emissions than the base case of utilizing local fuel.

V. CONCLUSIONS

The experimental work was done to assess the influence of adding different volumes between 100 to 400 ml of a commercial octane number additive to the fuel of a spark-ignition engine. Thoroughly, the corresponding performance indicators including torque, measurement of brake power, brake specific fuel consumption, and the emitted gases were experimentally evaluated. The following point specify the most important results.

- *An improvement of the engine performance indicators was conducted after adding the octane number additive compared to the local fuel.*
- *The highest torque can be achieved using 350 ml of octane number additive to the local gasoline fuel for the applied range of engine speed between 1000 to 5500 rpm.*
- *Using 5000 rpm of engine speed and 150 ml or 350 ml of octane number additive would guarantee the maximum brake power.*
- *The maximum reduction of the brake specific fuel consumption was conducted after adding 150 ml of octane number additive with the importance of utilising 5000 rpm of speed engine.*
- *The 150 ml of octane number additive has got the maximum brake thermal efficiency with the importance of using 5000 rpm.*
- *A clear reduction of gases emission was being noticed after adding the octane number additive to the local fuel.*
- *It is vital to use 350 ml of octane number additive at 3500 ppm of engine speed to ensure the lowest carbon monoxide emission. Significantly, low levels of exhaust gas pollutants were ascertained at high speeds range.*
- *The lowest nitrogen oxides emission can be conducted with 350 ml of octane number additive. However, the lowest speed engine of 1000 rpm is important to ensure the highest reduction of nitrogen oxides emission.*
- *The 3500 rpm of speed engine and 350 ml of octane number additive have obtained the lowest emission of unburned hydrocarbon.*
- *It was not recommended to use 400 ml of octane number additive due to the possibility of having an excessive rate of gases emission.*

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➢ *Conflict of Interest*

The authors declare that they have no conflict of interest

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