Performance, Emission and Visiographic Analysis of Gasoline Engine with MTBE and DIE Additives

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Abstract - *In this work, two oxygenated additives like methyl tert butyl ether (MTBE) and di-isopropyl ether (DIE) are identified for the experimental investigation by blending them to 5 ml with gasoline sole fuel. The performance and emission analysis were tested in twin cylinder SI engine with both additives blend with gasoline. The physical and chemical properties of the gasoline fuel and additives are tested through ASTM standards and reported. From the experimental results, it was found that brake thermal efficiency increased to 1.25% and emissions like HC and CO reduced to 10.7% and 17%, respectively for addition of MTBE and DIE. NOx emission found increased in the both additive cases. The Fuel spray images were captured by AVL Visio scope with pixel fly VGA Camera and necessary equipment's.*

Key Words: Gasoline engine, Methyl tert butyl ether, Di-isopropyl ether, Performance, Visio graph.

NOMENCLATURE:

MTBE	- Methyl tert butyl ether
DIE	- Di-isopropyl ether
Additive -1	- MTBE
Additive – 2	- DIE
Rpm	- Revolution per minute
HSU	- Hatridge smoke unit
Ppm	- Parts per million
BP	- Brake power
BTE	- Brake thermal efficiency
HC	- Hydrocarbon emission
CO	-Carbon monoxide emission
NOx	- Oxides of nitrogen emission
ASTM	- American Standard Testing Materials

1. INTRODUCTION

To modify the fuel quality, additives can be added in small quantity either to enhance engine performance or to reduce the emission.Fuel additives have been one of the most prolific innovations of liquid engineering additionally material science giving natural fuel sources and additional properties which help us drive that little extra out of them [1]. Whether it's an additive to differ a fuels burn rate, increase surface area, prevent corrosive effects, innovators have developed a range of additives over the years which give these fuels an added property which serves a pressing need from consumers. The fuel additives are generally interrelated with additives to gasoline and oil based fuels in the interest of environmental protection, un-burning emissions and increasing mileage, the innovation around additives has a broader impact of being able to change, alter or enhance specific attributes of a fuel whether liquid, solid or gas [2,3]. The Additives have been developed to increase combustion rates, as anti-oxidants, to effect burn rates, to empower fuels to work under extreme temperatures, reduce harmful emissions and more [4]. Over the years various hybrid compounds and blends have been engineered to create better fuels for industries commercial use and end consumers alike.Methyl tertiary butyl ether (MTBE) is a chemical compound obtained from a reaction between methanol and isobutylene [5]. Methanol is mainly derived from natural gas while isobutylene is derived either from natural gas or from by-products of fluid and steam crackers [6]. Its principal use is as an additive to automotive fuels. When blended into gasoline, MTBE enriches octane ratings and improves fuel combustion, thus reducing harmful exhaust emissions. Di-isopropyl ether is secondary ether that is used as a solvent. It is a colorless liquid that is marginally soluble in water, but miscible with organic solvents [7]. It is used as an oxygenate gasoline additive. It is acquired industrially as a byproduct in the production of iso-propanol by hydration of propane. Di-isopropyl ether is sometimes represented by the abbreviation "DIPE". Whereas at 20 °C, diethyl ether will dissolve 1% by weight water, DIPE only dissolves half as considerable. It is used as a specialized solvent to eliminate or extract polar organic compounds from aqueous solutions, e.g. phenols, ethanol, acetic acid. DIPE is used as antiknock agent Di-isopropyl ether can form explosive peroxides upon standing in air for long periods [8]. This reaction continues more easily than for ethyl ether, due to the secondary carbon next to the oxygen atom. Antioxidants can be used to prevent this process [9]. The stored solvent should therefore be tested for the existence of peroxides more often (recommended once every 3 months for di-isopropyl ether vs. once every 12 months for ethyl ether). Peroxides may be removed by shaking the ether with a solution of iron (II) sulfate. For safety causes, methyl tert-butyl ether is often used as an alternative solvent [10]. In this study to improve the performance and reduce the harmful emissions like HC and CO, MTBE and DIE additives are blend with gasoline fuel in the proportion of 5ml.

2. FUEL MODIFICATION

MTBE and DIE were added with gasoline fuel with 5ml/lit and kept in a homogenizer to make proper blend of fuel and additive. The thermo-physical properties of fuel before and after addition of MTBE and DIE have tabulated in Table 2 and chemical properties have tabulated in Table 1.

Table 1 Properties of MTBE and Di-isopropyl ether
(Source: **The European Fuel Oxygenates Association, 2006)**

Properties	Methyl tert butyl ether	Di Isopropyl Ether
Molecular formula	$CH_3OC(CH_3)_3$	$(CH_3)_3 COCH_3$
Octane number	116	118
Molecular weight (g/mol)	88	102
Boiling point (°C)	55.3	73.1
Oxygen content (% wt)	18.2	15.7
Vapor pressure (mmHg at 25°C)	270	128

Table 2 Physical and chemical properties of petrol, MTBE and Di-isopropyl ether
(**Source: ETA Laboratory, Chennai**)

Property	Petrol	Methyl tert butyl ether	Di isopropyl ether
Specific gravity	0.72	0.7463	0.7449
Kinematic viscosity	1.37	1.36	1.40
Flash point°C	-43	-11	-12
Fire point °C	-13	-9	-10
Pour point °C	-32	-18	-19
Gross calorific value (kJ/kg)	45650	45738	45664
Acidity as mg of KoH/gm	0.024	0.012	0.011
Density@ in gm/cc	0.71	0.7452	0.7440

3. EXPERIMENTAL SETUP

The experimental setup is shown in Figure 1. The level of the fuel and lubricating oil were checked before starting the engine. The eddy current dynamometer control unit panel is switched "ON' to note down the load, speed and temperature from the indicator provided in the panel board. Then the ignition switch is turned "ON" position. The fuel flowed from the fuel tank through the electronic fuel injection pump and then started the engine at no load condition. The engine was allowed to run with sole fuel at a constant speed of 2500 rpm for nearly 30 minutes to obtain steady state condition. The cooling water temperature reached 50°C. fuel consumption was measured by stop watch for one minute of fuel. In the same readings for 20%, 40%, 60%, 80% and full load were observed. After taking the required readings the ignition switch is turned "OFF" position to stop the engine and the eddy current dynamometer control unit panel was also switched "OFF".

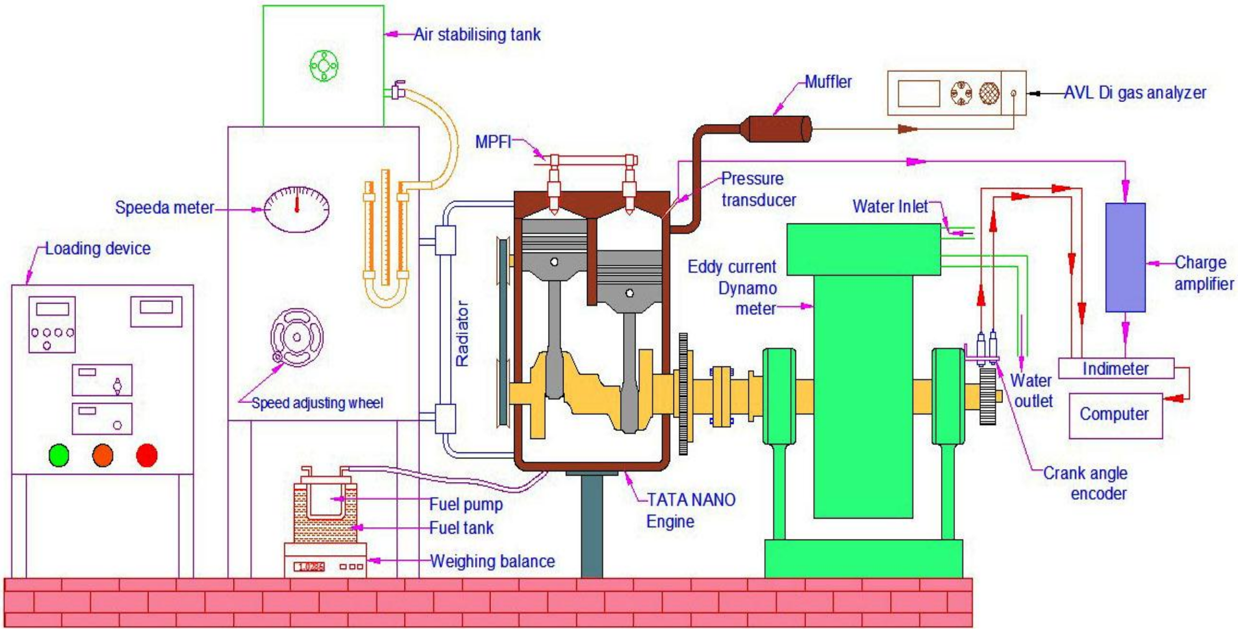

Figure 1 Experimental setup

Table 3 Specification of the test engine (TATA NANO)

Type	Vertical In-line Engine with MPFI
No. of Cylinder	2
Displacement	624 cc
Bore	73.5 mm
Stroke	73.5 mm
Compression Ratio	9.5:1
Fuel	Petrol
Cycle	4-Stroke
Max. Engine output	25.74 kW @ 5250 rpm
Max. Torque	48 Nm @ 3000 rpm
Speed	2500 rpm
Orifice Diameter	20 mm
Cooling System	Water
Loading Device	Eddy current Dynamometer

4. FUEL SPRAY VISUALIZATION

The spray visualization was studied through the AVL Visioscope with all the necessary equipment's. The Visioscope equipment was consists with the following accessories;

- Pixel fly VGA camera
- Visio Sparkplug
- Endoscopic unit
- Light Control unit with flash
- AVL Micro IFEM
- AVL Indimodule
- AVL Visio FEM
- Crank angle encoder
- AVL Visioscope 1.4 Software

The AVL Visioscope is a fully digital, triggerable video system specifically designed for IC Engine research. It is used to observe periodic phenomena in IC engines using a strobe. The images delivered by a digital CCD Camera are transmitted straight to the PC as digital data (and therefore with no loss of quality). Synchronization with the engine is achieved via an AVL Angle Encoder (365Cor365X). A strobe connected to the Light Unit is used for convenient correction angle adjustment. The proven endoscopy technology provides optical access to any type of series engine without interfering with the in-cylinder processes.

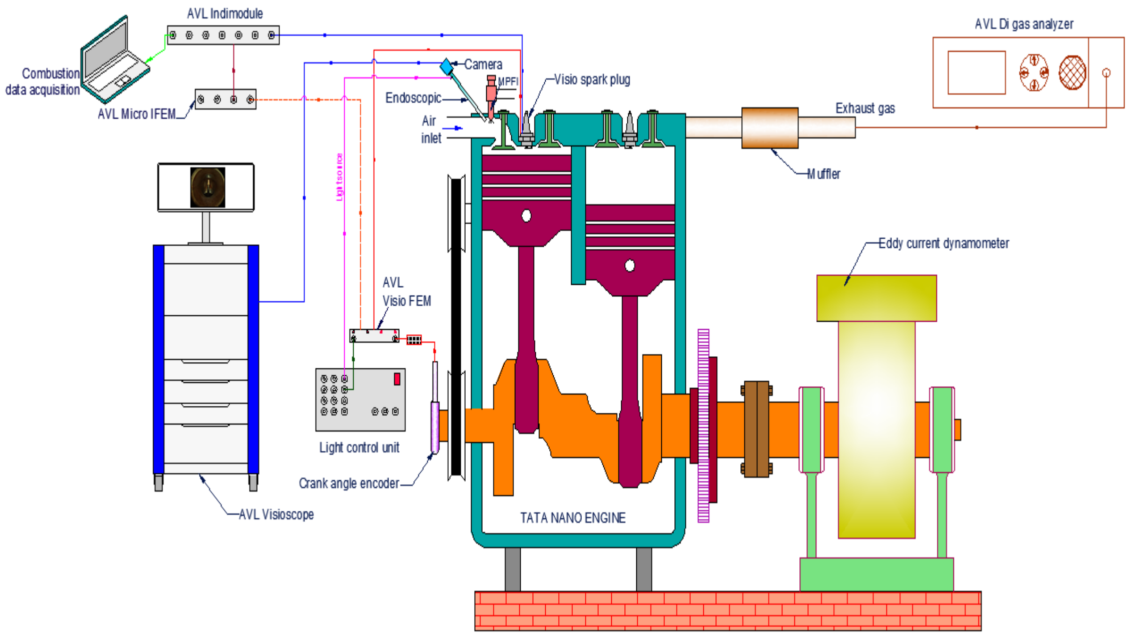

Figure 2 Experimental setup with AVL Visioscope

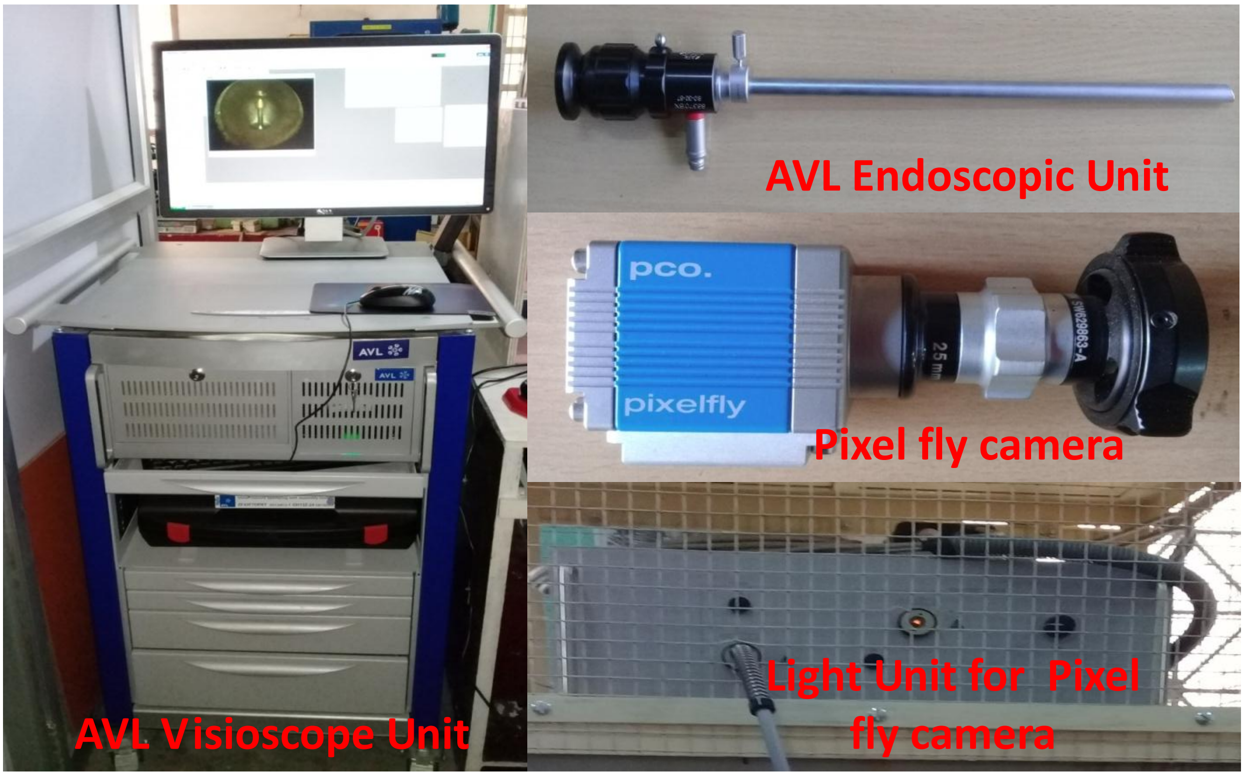

Figure 3 Photographic view of AVL Visioscope unit with accessories

Figure 4 Photographic view of endoscope fitted in test engine

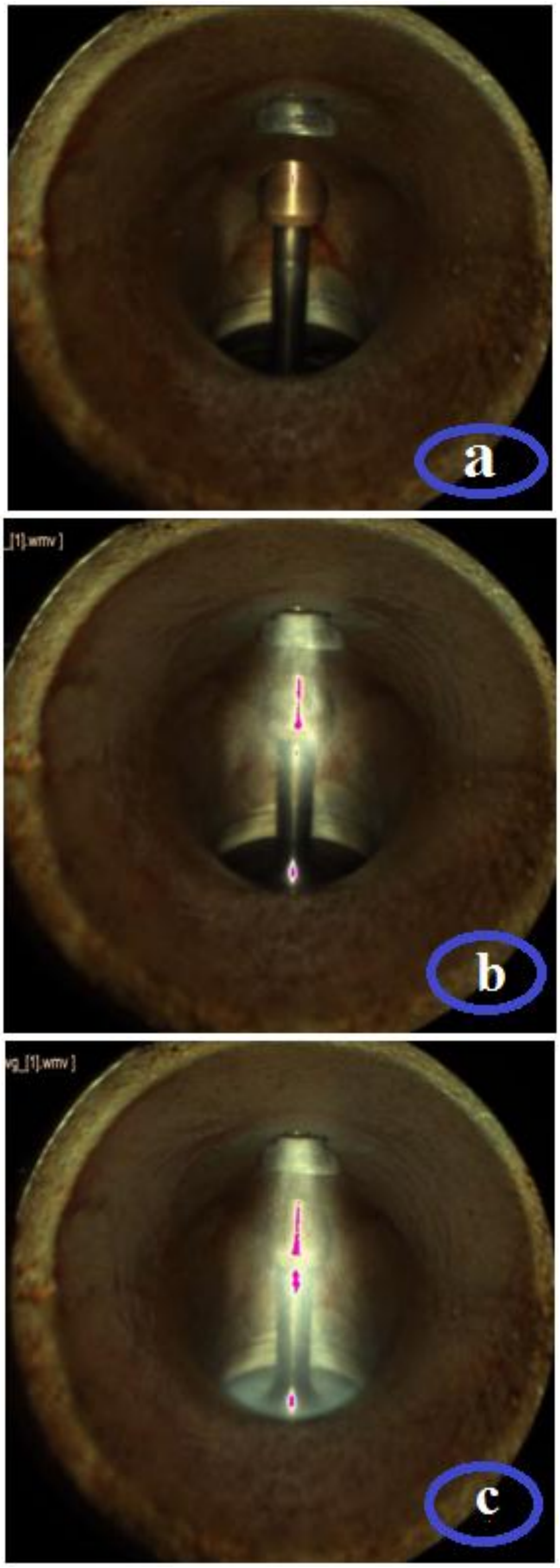

Figure 5 Photographic view of Spray Visualization (a) without fuel spray (b) with fuel spray (c) fuel spray ending

5. RESULT AND DISCUSSION

The experimental investigations were conducted by gasoline fuel with two types of oxygenated additives such as methyl-tert butyl ether and di isopropyl ether. The investigations were experimentally conducted in TATA NANO gasoline engine by various speed conditions of the engine.

5.1 PERFORMANCE CHARACTERISTICS

5.1.1 BRAKE THERMAL EFFICIENCY

The variations of brake thermal efficiency against speed for various blends of additives and gasoline fuel are shown in the Figure 6. The blend Additive-1(MTBE) having higher brake thermal efficiency when compared to that sole gasoline fuel. The Additive-1 gives maximum brake thermal efficiency of economy speed of 2800 rpm of the engine. It has an increase of 1.25% when compared to sole gasoline fuel. The brake thermal efficiency of Additive-1 and Additive-2 is 23.5%, 22.8% respectively at high speed of the engine. The reason for increasing brake thermal efficiency of Additive-1 is high calorific value and higher speed which gives better combustion process improves combustion efficiency and the oxygenated additives provides more oxygen presence in the combustion chamber.

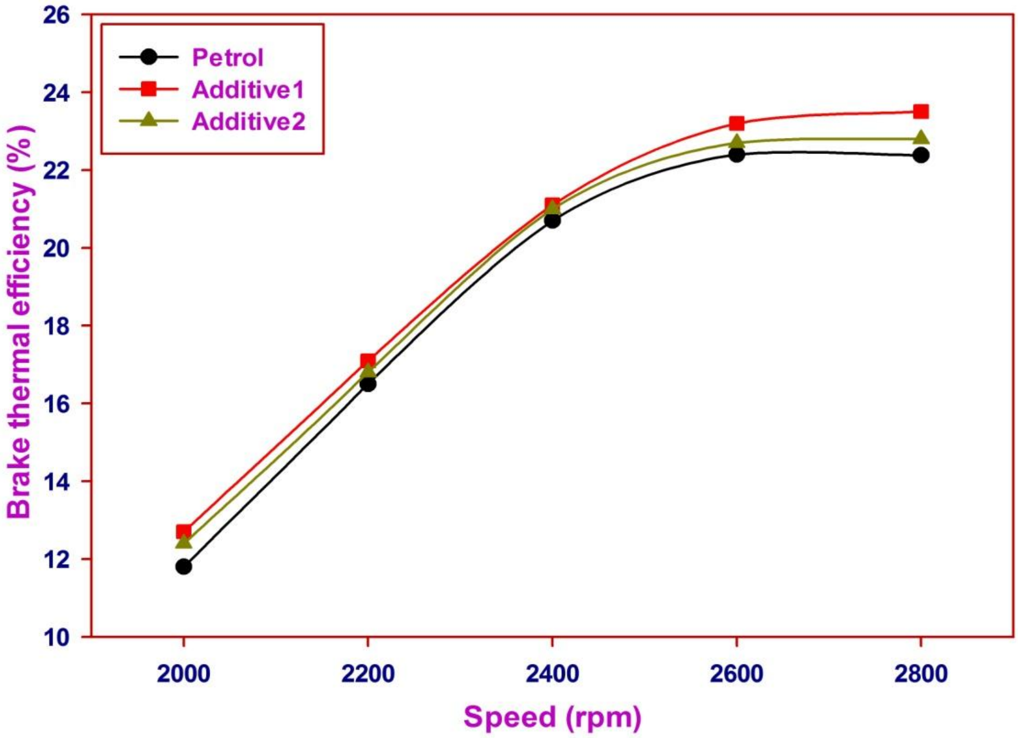

Figure 6 Variations of brake thermal efficiency with Speed

5.2 EMISSION CHARACTERISTICS

5.2.1 OXIDES OF NITROGEN (NOx)

The variations of NO_x emission against speed for various blends of additives and gasoline fuel are shown in the Figure 7. The NO_x emission is increases for the Additive-1 (MTBE) blend by 18% when compared to that of gasoline sole fuel. The oxygenated additives provides more oxygen (O_2) content gives better combustion thereby in-cylinder temperature is increased due to which an increased NO_x emission is observed for Additive-1 with sole gasoline fuel with maximum speed of the engine. The NO_x emission for sole gasoline fuel and Additive-1 is 28, 25 ppm respectively with full load condition and constant speed of the engine.

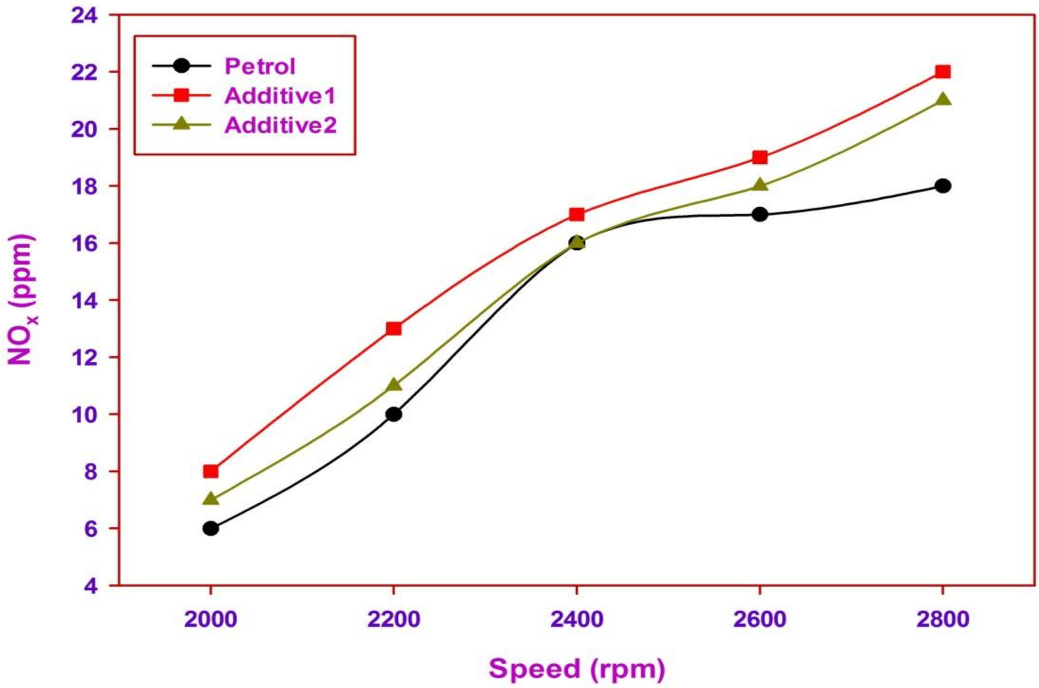

Figure 7 Variations of oxides of nitrogen with Speed

5.2.2 CARBON MONOXIDE (CO)

The variations of CO emission against speed for various blends of additives and gasoline fuel are shown in the Figure 8. Additive-1(MTBE) blend shows decreased CO emission with maximum speed of 2800 rpm, since the availability of additional oxygen content improve the combustion process and converts CO in to CO_2. It has a decrease of 17% when compared to that of sole gasoline fuel and maximum speed of the engine.

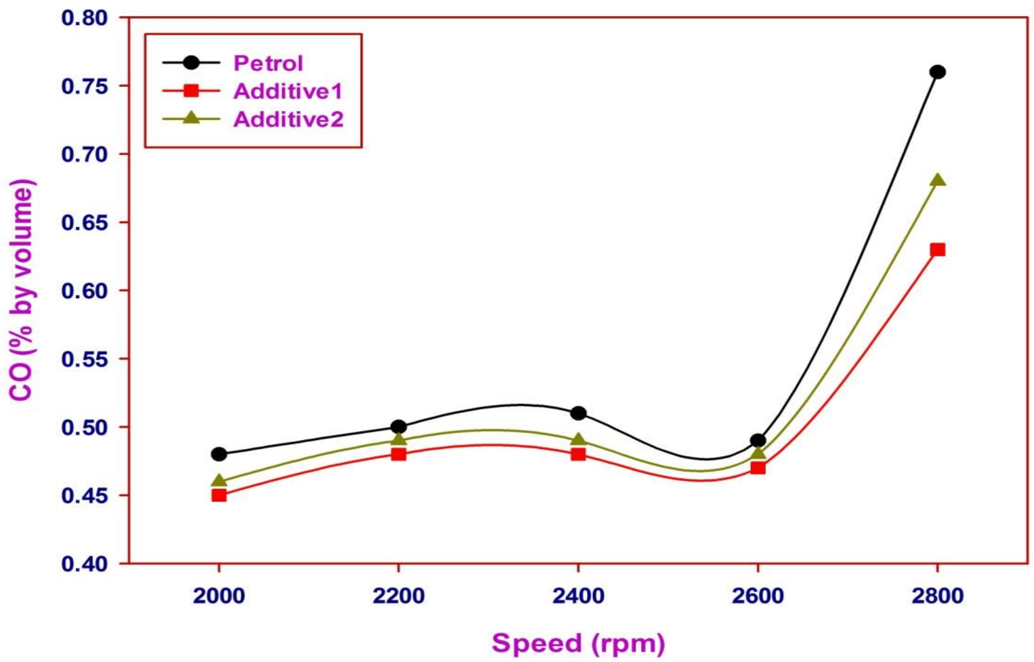

Figure 8 Variations of CO with Speed

5.2.3 HYDROCARBON (HC)

The variations of HC emission against speed for various blends of additives and gasoline fuel are shown in the Figure 9. Additive-1(MTBE) shows decreases in HC emission with economy speed of 2800 rpm when compared to that of sole gasoline fuel. The cause is due to complete combustion provided by the oxygenated additive. It has shown a decrease of 10.7% when compare to sole gasoline fuel. The HC emission for the Additive-1 and sole gasoline fuel is 28ppm, 25ppm respectively with maximum speed of the engine.

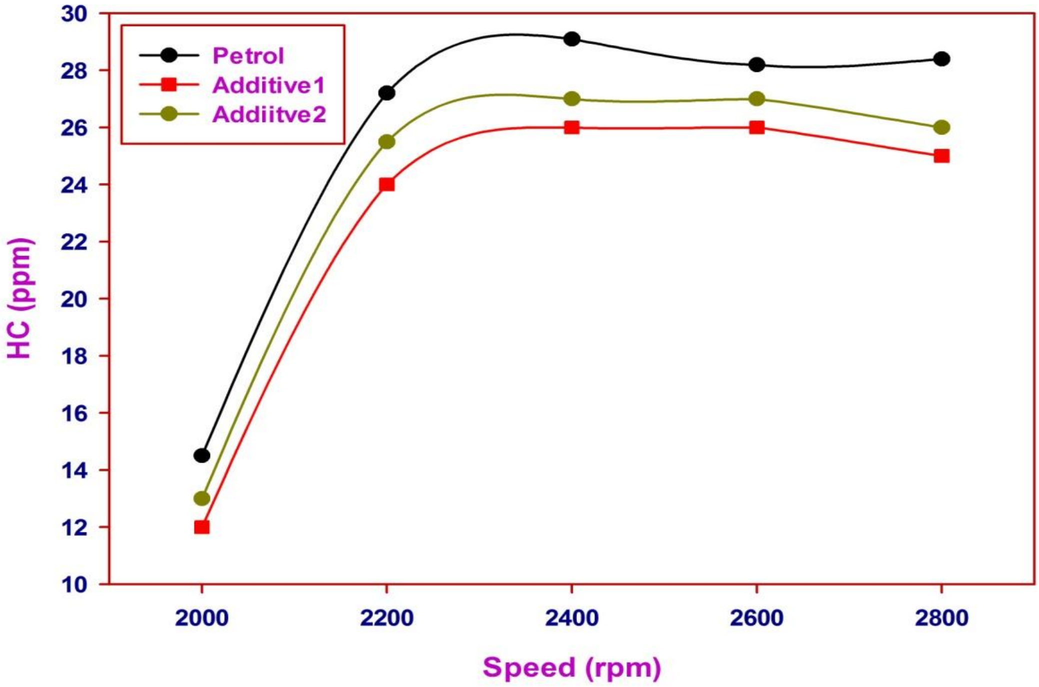

Figure 9 Variations of HC emission with Speed

CONCLUSION

The main conclusions of this study are;

1.The Additive-1 shows increased brake thermal efficiency than that of sole fuel. It has shown an increase of 1.25% when compare to sole gasoline fuel.

2.The Additive-1 gasoline fuel show significant reduction in CO, HC emission and increases of NO_x emission when compared to that of sole gasoline fuel. The decreases of CO, HC emission is 17%, 10.7% respectively and increases of NOx emission is 18%.

3.The fuel spray visualization images were captured through AVL Visioscope with pixel fly VGA camera, endoscopic unit and necessary equipment's.

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BIOGRAPHIES

Mohammed Shamim received the B.E. degree in Mechanical Engineering from Annamalai University, Faculty of Engineering and Technology, Annamalainagar, Chidambaram, Tamil Nadu in 2013 and Completed Masters of Engineering degree in Energy Engineering and Management from Annamalai University, Faculty of Engineering and Technology, Annamalainagar, Chidambaram, Tamil Nadu in 2017 respectively.

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