# Emission Reduction on Ethanol – Gasoline Blends using 1, 4 Dioxan

C.ANANDA SRINIVASAN and C.G.SARAVANAN

*Abstract* — **In this study, the effects of ethanol and unleaded gasoline with 1, 4 Dioxan blends on multi-cylinder SI engine were investigated. The test fuels were prepared using 99.9% pure ethanol and gasoline with 1,4 Dioxan blend, in the ratio of E 50+5 1,4 Dioxan, E 60+101,4 Dioxan, the rest gasoline. In this work, the performance and emission tests were conducted in a multi-cylinder petrol engine. The experimental results reveal the increase in brake thermal efficiency for the blends when compared to that of sole fuel. In this investigation, the emission tests are made with the help of AVL Di Gas analyzer, in which CO, $CO_2$, HC, $NO_X$ are appreciably reduced and $O_2$ is increased for all the blends when compared to sole fuel.**

**KEYWORDS: Ethanol, Carbon monoxide, Hydrocarbon, Oxides of Nitrogen, 1, 4 Dioxan.**

## I. Introduction

Ethanol ($C_2$ $H_5$ OH) is a renewable fuel. It can be produced from agricultural feed – stocks such as sugarcane and also from forestry wood wastes and agricultural residues. It can be also be derived chemically from ethylene or ethane. Ethanol has a simple molecular structure with C, H and O atoms and with well defined physical and chemical properties. Ethanol can be employed as a transportation fuel even in its original form and can also be easily blended with fuels such as gasoline and diesel.

Currently, there is a lot of interest in ethanol production from renewable feed – stocks, to minimize the emissions of carbon dioxide, a greenhouse gas which contributes to global warming. The addition of ethanol to gasoline results in the enhancement of the octane number of blended fuels and changes the distillation temperature, apart from reducing the engine emissions. [12].

The reserves of petroleum based fuels are being rapidly depleted, because of the increased use of fossil fuels for energy production. It is well known that the future availability of energy resources as well as the need for reducing the emissions from the fuels used has increased the need for the utilization of regenerative fuels. (8)

Alcohol such as ethanol, a colorless liquid with mild characteristic odor can also be produced from fermentation of biomass. Usage of alcohol as fuel for SI engine has some advantages when compared to gasoline. Ethanol has better anti – knock characteristics than gasoline. The engine thermal efficiency can be improved with the increase in compression ratio. (9)

C.ANANDA SRINIVASAN is with the Faculty of Engineering and Technology, Department of Mechanical Engineering, Annamalai University, Annamalainagar – 608002, Tamil Nadu, India (corresponding author phone: +91 04144 - 239733; fax: +91 04144 - 238275; e-mail: anandsrinivasa@yahoo.com).

C.G.SARAVANAN is with the Faculty of Engineering and Technology, Department of Mechanical Engineering, Annamalai University, Annamalainagar – 608002, Tamil Nadu, (e-mail: rsdk66@yahoo.com).

Alcohol burns with lower flame temperature and luminosity owing to decreasing the peak temperature inside the cylinder, so that the heat loss and NOx emissions are lower. Ethanol has high latent heat of vaporization. The latent heat cools the intake air and so there is increase in density and volumetric efficiency. However, the oxygen content of ethanol reduces the heating value compared to gasoline. It is evident that Ethanol can be used as fuel in SI engines. (10)

Hsieh et al, (1) investigated experimentally the engine performance and emission of a spark ignition engine, using ethanol–gasoline blend fuels in the ratios of 5%, 10%, 20% and 30% respectively. The results showed that when the ethanol rate was increased the heating value of the blended fuel was found decreased but increased the engine torque.

Ethanol has high affinity for water as it contains certain amount of water. This is not a problem for pure ethanol because it fully mixes with water but some serious problem can rise when gasoline – ethanol blends is used. Phase separation can occur in gasoline – ethanol blends since gasoline and ethanol are immiscible. This problem can be prevented by using semi – polar co-solvents (solubility improvers) such as isopropanol. (4)

Guerrieri et al. (2) tested gasoline and gasoline–ethanol blends on six in-use vehicle to determine the effect of ethanol content on emissions and fuel economy. HC and CO emissions as well as fuel economy decreased in most vehicles, as the ethanol content increased in the fuel. At the highest ethanol concentration, 40%, HC emission, CO emission and fuel economy decreased by about 30%, 50% and 15%, respectively.

Wu et al. (3) investigated the effect of air–fuel ratio on SI engine performance and pollutant emissions using ethanol–gasoline blends. The result of engine performance tests showed that torque output improved when using ethanol– gasoline blends. However, there is no appreciable difference on the brake specific heat consumption. CO and HC emissions reduced with the increase of ethanol content in the blended fuel. It is proved in their study that by using 10% ethanol fuel, pollutant emission can be reduced efficiently.

He et al. (5) investigated the effect of ethanol–gasoline blends on emissions and catalyst conversion efficiencies in a spark ignition engine. The blended fuels reduced CO, HC and NOx emissions.

Fikret et al (13) investigated the study of a new dual fuel system could be serviceable by making simple modifications on the carburetor and these modifications would not cause complications in the carburetor system. The carburetor was redesigned to be able to use gasoline – Alcohol mixture as a fuel. By using ethanol – gasoline blend, with 60% of Ethanol and 40% of Gasoline was exploited to test the performance, the fuel consumption and the exhaust emissions.

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Bang – Quan He et al (14) had studied the effect of ethanol blended gasoline fuels on emissions and catalyst conversion efficiencies was investigated in a SI engine with an EFI system. Tailpipe emissions of THC,CO and NOx have close relation to engine – out emissions, catalyst conversion efficiency, engine's speed and load, air/fuel equivalence ratio. Moreover, the blended fuels can decrease brake specific energy consumption.

General conclusions arrived from the above literature review are that ethanol can be produced abundantly and economically and it will be an attractive alternative fuel for S.I. engines. It can be used either as a pure fuel or as a gasoline additive. Gasoline – ethanol blends including ethanol at low proportions can be used without any engine modifications but pure ethanol requires major modifications to the engine design and fuel system. Fuel modification technique is employed in the form of fuel additives blended with gasoline or ethanol – gasoline blends to enhance the fuel properties. Fuel additives are very important, since many of these additives can be added to fuel in order to improve its efficiency and its performance. One of the most important additives to improve fuel performance is oxygenates (oxygen containing organic compounds).

Palmer (7) reported that all oxygenated blends gave a better anti – knock performance during low speed acceleration than hydrocarbon fuels of the same octane range. Consequently, the use of gasoline – ethanol blends with fuel additives in the S.I. engines is more practical than using ethanol alone. Based on this, the present experimental studies have been focused on fuel modification technique using gasoline – ethanol blends with fuel additives on S.I. engine to analysis the performance and exhaust emissions.

This paper aims to run the engine with different percentage of blending of gasoline and ethanol with the oxygenated additive 1,4 dioxan to reduce the exhaust emissions and also to increase the brake thermal efficiency of the engine. The percentages of blending are given in Table 1.

**Table 1 Sample volumetric composition**

| Sample Name | Gasoline | Ethanol | 1,4 Dioxan |
|---|---|---|---|
| Sample 1 | 45 | 50 | 5 |
| Sample 2 | 30 | 60 | 10 |
| Sole Fuel | 100 | ----- | ----- |

**Table 2 Properties of different Fuels**

| | **Sole fuel** | **Sample 1** | **Sample 2** |
|---|---|---|---|
| Calorific value in MJ/kg | 45.55 | 35.042 | 31.735 |
| Specific gravity | 0.7 | 0.751 | 0.757 |
| Density@$15^0$ C in $gr/cm^3$ | 0.72 | 0.7675 | 0.7735 |
| Kinematic viscosity @ $40^0$C in $m^2$/sec. | 0.88E-4 | 0.76E-4 | 0.84E-4 |
| Flash Point by Abel Method | $-43^0$C | $-41^0$C | $-39^0$C |

**Table 3 Error Analysis**

| **Parameters** | $O_2$ | NOx | HC | CO | λ |
|---|---|---|---|---|---|
| **% of Errors** | 1.05 | 0.94 | 1.03 | 0.09 | 0.5 |

## II. EXPERIMENTAL SETUP

A vertical inclined, water cooled, three cylinders, four stroke, 86.5 mm bore, 72 mm stroke, 796 cc displacement,8.7:1 compression ratio,12.56 kW power with rated speed of 3000 rpm and ignition timing of $10^0$ bTDC, with MPFI [Maruthi Omni] engine was used for the experimental work. The engine was coupled to an eddy current Dynamometer for load measurement. Hydrocarbon, carbon monoxide, Carbon dioxide, was measured by using AVL 5 – gas analyzer. NOx emissions were measured by using exhaust gas analyzer. Before the experiments the emission analyzer and the dynamometer were calibrated.

The experiments were performed at variable speeds of 2000,2200,2400,2600 & 2800 rpm with constant output of 7.53 KW. The volumetric percentages of ethanol – gasoline blends with additives are in the ratio of E60 + 10, E50 + 5. These represent the ratios of ethanol and 1,4 Dioxan amount in the total blend. Ethanol with a purity of 99.9% was used in the blends. The schematic view of the test equipments are shown in Fig. – 1.

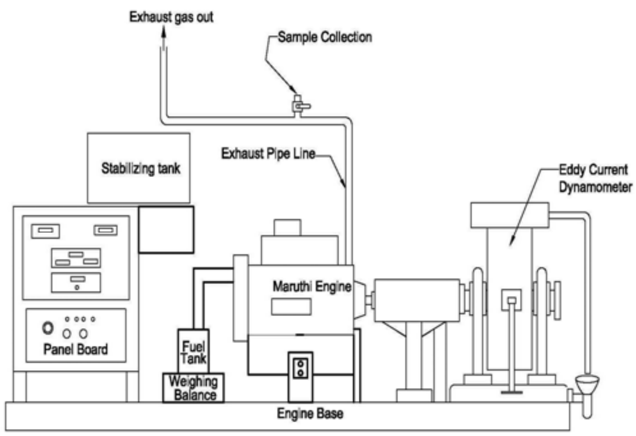


FIGURE – 1 EXPERIMENTAL SETUP

The engine was allowed to run with gasoline at various speed of 2000,2200,2400,2600 & 2800 rpm with a constant output of 7.53 KW. After completing the experiment with gasoline, the experiment was conducted with sample 1, sample 2; Fresh gasoline procurements were made for experiments with each sample blend to reduce the effect of storing. Hence to compare the results of the sample blend runs, base values with gasoline were obtained separately for each sample blend. After completing the experiments with the first sample blend, the engine was allowed to run for about half an hour with gasoline to eliminate the interference of the first sample blend. Then for each sample blend, after completion the gasoline run was repeated. The entire sample blends were tested by similar procedure.

## III. RESULT AND DISCUSSION

The effects of ethanol addition to gasoline with additives on SI engine performance and exhaust emissions at variable engine speeds were investigated.

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*(a) Brake Thermal Efficiency*

The effect of the gasoline – ethanol with 1, 4 Dioxan blends, on the brake thermal efficiency is shown in Fig.2. The brake thermal efficiency is higher for all the samples when compared to the sole fuel. For the first stage the brake thermal efficiency is 27% for sample 2 at 2400 rpm is higher when compared to the sole fuel. A marginal increase of brake thermal efficiency is observed for all samples at all speeds as shown in Fig.2. Among the samples, sample 2 shows the maximum brake thermal efficiency. This is due to the increase in octane number of the samples.

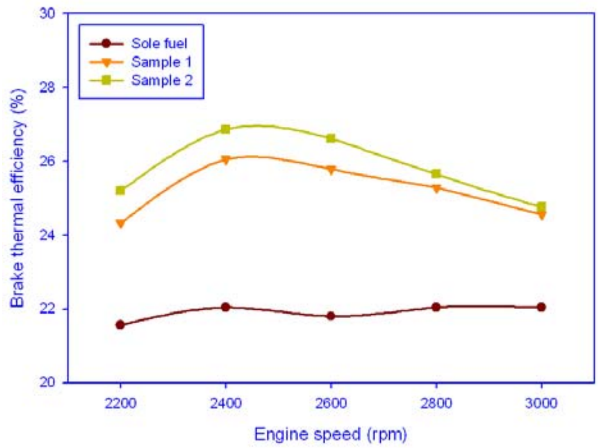


Fig. 2 Brake Thermal Efficiency Vs Engine Speed

*(b) CO Emissions*

The effect of the gasoline – ethanol with 1, 4 Dioxan blends, on the CO emissions is shown in Fig.3. It can be seen that ethanol with oxygenated additive concentration increases and reduces the CO emissions. It is noted that in sample 1 & 2 at 2000 rpm, the concentration of CO emission decreases 0.04 % by volume. The variation of CO emission for the sample 1 & 2 is less when compared to that of the sole fuel. The reason is due to the increase in the percentage of ethanol and additive concentrations as a result to leaner combustion due to the presence of oxygen in ethanol. Owing to the leaning, CO emissions decrease tremendously. In general, for all concentration blends CO emissions are reduced when concentration increases.

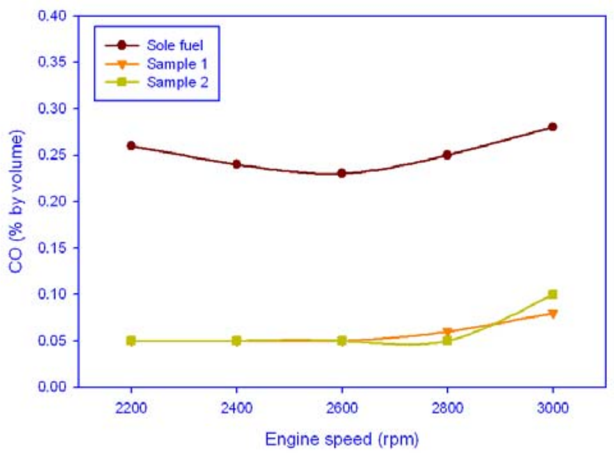


Fig.3 CO Vs Engine Speed

*(c) $CO_2$ Emissions*

The effect of the gasoline – ethanol with 1, 4 Dioxan blends on $CO_2$ is shown in Fig.4. In sample 2, the $CO_2$ value is 5.4 % by volume at 2200 rpm, which is minimum than sole fuel. It is obvious that there is significant reduction in $CO_2$ emissions when using ethanol blends samples. There is appreciable reduction in sample 2. This is due to the presence of maximum blend of 1, 4 Dioxan in the ethanol – gasoline blends.

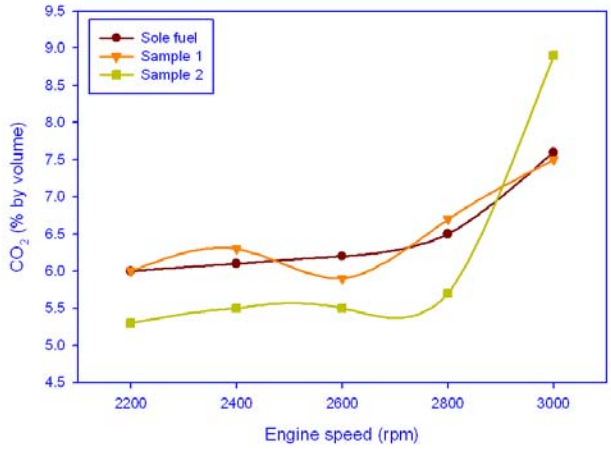


Fig. 4 $CO_2$ Vs Engine Speed

*(d) HC Emissions*

The effect of alcohol percentage in the blend additives on the HC emissions is shown in the fig.5. In all the samples there is decrease in the HC emissions at all speeds. The amount of HC emissions in all samples is lower when compared to that of the sole fuel at all the speeds, it is due to the fact that, ethanol has lower flame speed compared to sole fuel operation. As a result, less mass fraction of fuel is burnt in the case of ethanol blends gasoline with 1, 4 Dioxan. In sample 2, the value of the HC emissions is 15 ppm at 2600 rpm which is minimum than the sole fuel.

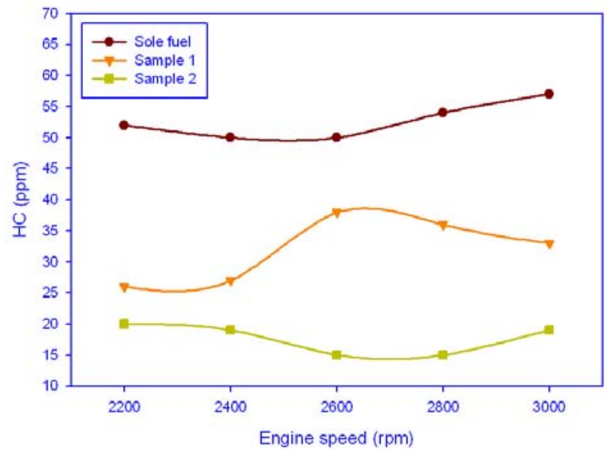


Fig. 5 HC Vs Engine Speed

*(e) $NO_X$ Emissions*

The effect of the gasoline – ethanol with 1,4 Dioxan blends on the Speed versus NOx is shown in Fig.6. It can be seen that ethanol gasoline blend decreases NOx emissions. This is the main reason attributed to the properties of ethanol blends. For sample 2 it is found that NOx level is significantly reduced for all speeds. The percentage of

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reduction in NOx level ranges from 600 to 300 ppm for the sample 2 which is slightly lesser than other samples. This indicates that they have lower heating value of ethanol than gasoline. This decreases the combustion heat energy and lowers the combustion temperature in the cylinder. In sample 2, the NOx value is 320 ppm at 2200 rpm which is minimum than other samples.

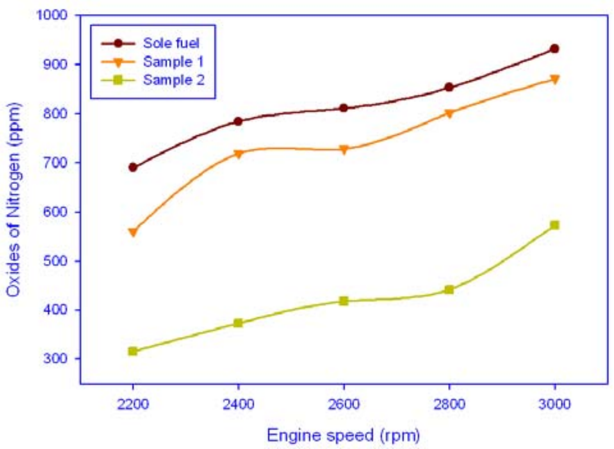


Fig.6 NOx Vs Engine Speed

*(f) $O_2$ Emissions*

The effect of the gasoline – ethanol with 1,4 Dioxan blends, on the Engine Speed is shown in Fig. 7. All the samples were found to increase the $O_2$ emissions at all speeds. It is found in sample 2 has the maximum oxygen content in the exhaust gas is 13.18 % by volume at 2200 rpm. The reason for the increase in oxygen content in the exhaust gas is due to the increase in ethanol and additive percentage.

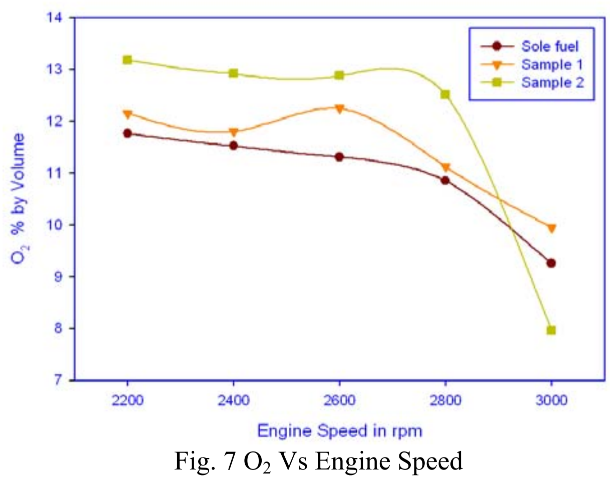


Fig. 7 $O_2$ Vs Engine Speed

## IV. CONCLUSION

**From the study, the following conclusions can be deduced:**

1. Using of ethanol blend as a fuel additive to gasoline causes improvement in engine performance and exhaust emissions.
2. Ethanol addition results in the increase in brake thermal efficiency.
3. Using of ethanol blended gasoline leads to a significant reduction in exhaust emissions. For all engine speeds the values of CO, $CO_2$, HC and NOx have been reduced. On the other hand $O_2$ emissions have been increased significantly.
4. The **sample 2** with ethanol blend and oxygenated additive gives the best results for the Engine Performance and Exhaust emissions.
   a) The Brake Thermal Efficiency is 26.86% at 2400 rpm
   b) The CO emission is reduced to 0.05 % by Volume at 2200 rpm to 2800 rpm
   c) The $CO_2$ emission is reduced to 5.3 % by Volume at 2200 rpm
   d) The HC emission is reduced to 15 ppm at 2600 rpm & 2800 rpm
   e) The NOx emission is reduced to 316 ppm at 2200 rpm

5. The addition of 60% of ethanol blend gasoline with additive is achieved in our experiments without any problem during engine operation. On the other side without additives the performance gave better result up to 40 % beyond that it is absorbed that abnormal combustion, vibration and starting problem is achieved in our experimental investigation.

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