INFLUENCE OF DIETHYL ETHER BLEND IN SPARK IGNITION ENGINE PERFORMANCE AND EMISSIONS OPERATED WITH GASOLINE AND ETHANOL

by

Balaji DHANAPAL[a*], Mani Varmaa SELVAM NAGAMANI[a], and Senthil Kumar PACHAMUTHU[b]

[a] Department of Automobile Engineering, Velammal Engineering College, Chennai, Tamil Nadu, India
[b] Department of Automobile Engineering, Madras Institute of Technology, Chennai, Tamil Nadu, India

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This paper investigates the performance and emission characteristics of single cylinder four stroke petrol engine using unleaded gasoline with combination of ethanol and diethyl ether. Exhaust emissions were analysed for CO, HC, NO_x, and CO_2 by varying engine torque and engine speed. The result showed that the blend of unleaded gasoline with diethyl ether increases the octane number which in turn increases the power output which leads to increase in the brake thermal efficiency of the engine. The CO, HC, and NO_x emissions concentrations in the engine exhaust decreases while the CO_2 concentration increases. The use of diethyl ether and ethanol blends as a fuel additive to unleaded gasoline causes an improvement in performance and significant reduction in exhaust emission.

Key words: *fuel additive, gasoline-diethyl ether blend, exhaust emissions*

Introduction

It is the dream of engineers and scientists to develop engines and fuels that have lower quantity of harmful emissions and higher performance proportionately. The lower the emission from the engine, the lower the impact on the environment. Air pollution is largely influenced by the exhaust of motor vehicles and the combustion of fossil fuels. Legislations around the world have set forth many regulatory laws to control the emissions from engines. One among the serious problems faced by the modern society is the drastic increase in environmental pollution from internal combustion (IC) engines. Vehicles equipped with spaek ignition (SI) and compression ignition (CI) engines are equally responsible for the emission of different kinds of pollutants. Emissions such as CO, HC, and NO_x have direct hazardous impact, while others are secondary pollutants such as ozone, *etc*., which undergo a series of reactions in the atmosphere and become hazardous to health [1-3]. The emissions exhausted into the surroundings pollute the atmosphere and cause alarming effects such as global warming, acid rain, smog, odors, and respiratory and other health hazards. The need for alternative fuel is essential to replace the conventional fuels and reduce environmental effects. A pollutant changes the equilibrium of

* Corresponding author; e-mail: balsnaga2002@yahoo.com

environment under normal condition. The CO_2 may not be considered as pollutant as nature recycles it and produces oxygen but in a confined area if CO_2 exceeds 5000 ppm then it becomes a potential health hazard [4, 5]. The root cause for these emissions is non-stoichiometric combustion, dissociation of nitrogen and impurities in the fuel and air. The transportation which uses IC engines is the major sector for the economic growth. The major exhaust emissions HC, CO, NO_x, SO_2, solid particles, *etc*., are and performance is increased by adding the suitable additives to the fuel reduced with the present technology. Additives are integral part of today's fuel. Together with carefully formulated base fuel composition they contribute to efficiency and long life. They are chemicals, which are added in small quantities either to enhance fuel performance, or to correct a deficiency as desired by the current legislation. They can have surprisingly large effects even when added in little amount [6]. Additives are blended into fuel by refineries or end users. However, use of metallic additives such as lead was subsequently discontinued mainly because of concern about the toxicity of the barium compounds in the exhaust emission. But the interest is revised recently to verify the possible use of additives to reduce emission level. Alcohol has been used as a fuel for auto-engines since 19th century; but is not widely used because of its high price. Alcohol is one of the fuel additive (methanol, ethanol) has some advantage over gasoline such as better antiknock characteristics and the reduction of CO and HC emissions. Houghton-Alico [7] has made a study on alcohol, production and potential. Several additives (oxygenated organic compounds) such as methanol, ethanol, tertiary butyl alcohol and methyl tertiary butyl ether are used as fuel additives. Although having these advantages, due to limitations in technology, economic and regional considerations alcohol fuel still cannot be used extensively. Since ethanol can be fermented and distilled from biomasses, it can be considered as renewable energy under the environmental consideration, using ethanol blended with gasoline is better than methanol because of its renewability and less toxicity.

Many researchers have worked on the emission control and performance enhancement of SI engines. Winnington and Siddique [8] Hamdan and Jurban [9] and El-Kassaby [10] have studied the effect of using ethanol-gasoline blends. They used maximum of 15% of ethanol in ATd 34 engine. Palmer [11] has conducted a test on gasoline engine containing oxygenates. The effect of oxygenate in gasoline on exhaust emission and performance in a single cylinder, four stroke SI engine was studied by Taljaard *et al*. [12], Balaji *et al*. [13], and Balki *et al*. [14]. Ethanol can be produced form azeotropic solution by pressure swing adsorption and it was studied by Pruksathorn and Vitidsant [15, 16]. The effect of compressed natural gas on performance and emission in a IC engine was studied by Abu Bakar and Semin [17], Semin and Abu Bakar [18], and Kaleemuddin and Rao [19].

Based on the economic and environmental considerations, an attempt has been made in this work to study the effects of diethyl ether and ethanol content in the gasoline blended fuel. In order to reduce the emissions and to improve the performance of petrol engine, the fuel blending technique has been carried out. Two fuel additives were mixed for this purpose. Various proportions of these fuel additives were mixed with the gasoline. The engine performance analysis and emission levels were measured, running the engine at varying load and constant speed. Encouraging results were obtained and the work carried out is presented. The objective of the present work is to investigate the effect of varying engine torque on the engine performance and exhaust emission working with different diethyl ether fuel blends.

Experimental set-up and method

The engine is a 100 cc 4 stroke, single cylinder SI engine loaded by an eddy current dynamometer. Table 1 lists some of the important specification of the engine under test. The schematic layout of the experimental set-up is shown in fig. 1. The engine was coupled to a eddy cur-

Table 1. Engine specifications

Engine make and model	Bajaj engine
Engine type	Four stroke, single cylinder air cooled
Bore	70 mm
Stroke	90 mm
Cubic capacity	100 cc
Compression ratio	7.4:1
Rated power	5.2 kW
Rated speed	6500 rpm
Fuel	Petrol

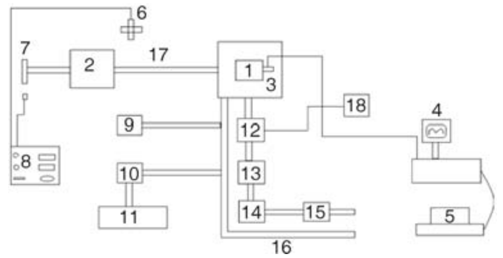

Figure 1. Experimental set-up
1 – engine, 2 – eddy current dynamometer, 3 – electric pressure pickup, 4 – personal computer, 5 – printer, 6 – load sensor, 7 – rpm counter, 8 – dynamometer control panel, 9 – exhaust gas temperature, 10 – moisture separator, 11 – exhaust gas analyzer, 12 – carburetor, 13 – air filter, 14 – air box, 15 – orifice meter, 16 – exhaust pipe, 17 – shaft, 18 – fuel measuring unit

rent dynamometer which is equipped with an instrument cabinet fitted with a torque gauge, electric tachometer and switches for the load remote control. Fuel consumption was measured by using a calibrated burette and a stopwatch with an accuracy of 0.2 s. The concentration of exhaust emission (CO, HC, NO_x) and air fuel ratio were measured using a Sun glass analyser MGA 1200. The analyser has a non-dispersive infrared molecule for CO, HC, and NO_x.

The engine was cranked and allowed to warm up and pick up the load for a period of 20-30 min. The air fuel ratio was adjusted to yield maximum power on unleaded gasoline. Engine test were performed at constant engine speed at 3/4th throttle opening position by varying engine torque. The speed was set constant. Before running the engine to a new fuel blend, it was allowed to run till the remaining fuel is cleared from the previous experiment. For each experiment, three runs were performed to obtain an average value of the experimental data. The variables that were continuously measured include engine speed (constant), torque, time required to consume 100 cc of fuel blend, CO, HC, NO_x emission, and exhaust gas temperature. The parameters such as fuel consumption rate, volumetric efficiency, brake power, brake thermal efficiency (BTE) were estimated by standard equations.

Results and discussion

The effect of diethyl ether and ethanol addition to unleaded gasoline on SI engine performance and exhaust emissions at 3/4th throttle opening at various engine torque were investigated.

Diethyl ether and ethanol in gasoline blends

Performance analysis

Fuel consumption. The effect of ethanol and diethyl ether in unleaded petrol blends for the fuel consumption is shown in fig. 2. This figure illustrates that the increase in the fuel consumption directly influences the engine torque at

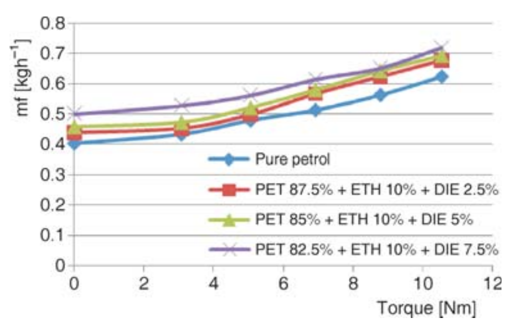

Figure 2. Variation of fuel consumption with engine torque

constant engine speed. This behavior is attributed to the lower heating value per unit mass of the ethanol and diethyl ether fuel, which is distinctly lower than that of the petrol fuel. Therefore, the amount of fuel introduced in to the engine cylinder for a given desired fuel energy input has to be greater with the ethanol and diethyl ether fuel.

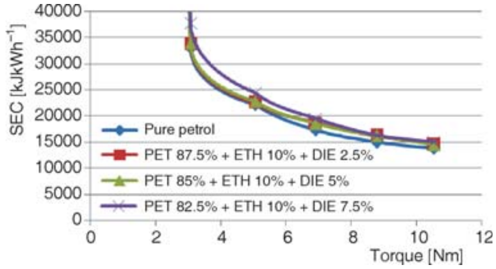

Figure 3. Variation of SEC with engine torque

Specific energy consumption. The effect of using ethanol, diethyl ether, petrol blends on brake specific energy consumption (SEC) is shown in fig. 3. Since ethanol and diethyl ether have low heating value than the pure petrol, in order to produce the same power at the same operating conditions, more fuel will be burned as the proportion of diethyl ether increases. As a result SEC increases.

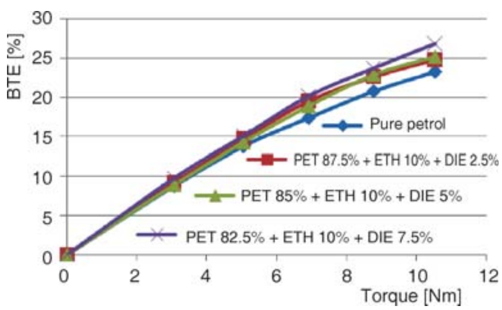

Figure 4. Variation of BTE with engine torque

Brake thermal efficiency. Figure 4 presents the effect of ethanol, diethyl ether-petrol blends on BTE. The figure states that, as the BTE increases the engine torque also increases. The BTE was calculated at various load conditions at constant engine speed such that at part load (50% load) recorded with 10% ethanol and 2.5% diethyl ether in the fuel blend was found that the thermal efficiency was about 15% and for 10% ethanol and 5% diethyl ether in the fuel blend the thermal efficiency recorded 14.5% and for 10% ethanol and 7.5% diethyl ether in the fuel blend is about 14.8% at constant engine speed.

The thermal efficiency for pure petrol is about 14.2% only. This is because of latent heat of vaporization of ethanol and diethyl ether fuel blends which is comparatively higher than petrol. Since it will reduce the intake charge temperature thereby density of intake charge has also increased which results in the increase in volumetric efficiency. Moreover, diethyl ether and ethanol blends have more volatility than petrol so that complete combustion takes place thereby increase in thermal efficiency.

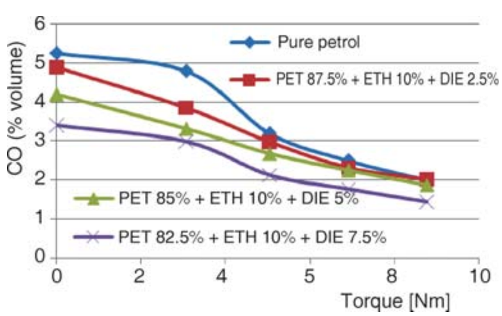

Figure 5. Variation of CO with engine torque

Emission analysis

Carbon monoxide. The effect of the ethanol and diethyl ether percentage in the fuel blend on CO emission is shown in fig. 5. Figure shows that the CO emission decreases as compared with pure petrol fuel for various blends. At the maximum load for all the fuels the specific emission of CO was around 1.3-2% volume. At part load, the specific emission of CO was found to be 2.5% volume for mixture of ethanol and diethyl ether (10% ethanol and 7.5% of diethyl ether) and for petrol it is found to be 4.2% volume. This effect is attributed because the stoichiometric air-fuel ratio of the ethanol and diethyl ether blends decreases and increase of actual air-fuel ratio of the ethanol and diethyl ether blends because of the excess amount of oxygen content present in the ethanol.

Nitrogen oxide. The effect of the ethanol and diethyl ether percentage in the fuel (pure petrol) blend in NO_x emission is shown in fig. 6. The Figure shows that the NO_x emission is comparatively lower for ethanol and diethyl ether blends than petrol. This is because of peak pressure of ethanol and diethyl ether blends which decreases at the same time the peak cycle temperature of the ethanol and diethyl ether fuel blends also decreases. So, NO_x emission decreases for all ethanol and diethyl ether fuel blends.

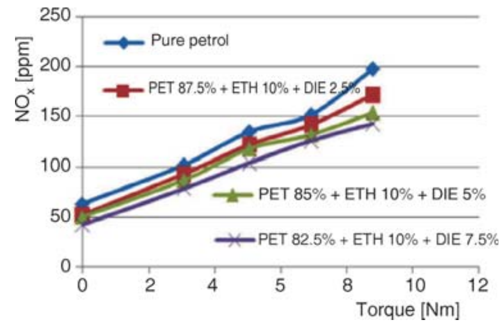

Figure 6. Variation of NO_x with engine torque

Hydrocarbons. The effect of ethanol and diethyl ether fuel blend percentage on HC emission is shown in fig. 7. It attributes the HC emission, whereby decreases in HC emission is observable when compared with pure petrol fuel for various blends. At full load condition the value of HC for diethyl ether blends (7.5%) was 155.5 ppm whereas for petrol it was about 185.5 ppm.

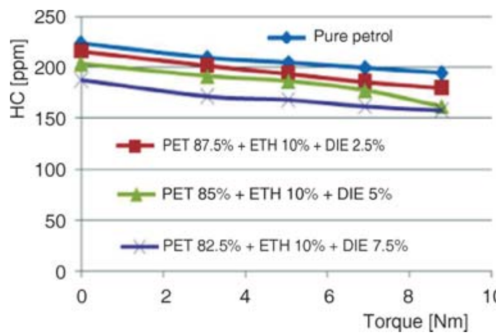

Figure 7. Variation of HC with engine torque

Due to the complete combustion of the blends these emissions are decreased considerably. This effect is recognized because the stoichiometric air-fuel ratio of the ethanol and diethyl ether blends decreases and increase of actual air-fuel ratio of the ethanol and diethyl ether blends as a result of the oxygen content in the ethanol and diethyl ether mixture.

Carbon dioxide. The effect of the ethanol and diethyl ether fuel blend in CO_2 emission is shown in fig. 8. It is observed that the ratio of CO_2 increases as compared with pure petrol fuel for various ethanol and diethyl ether blends. The CO_2 concentrations have an opposite behavior when compared to CO concentrations. This is due to improving combustion process as a result of the oxygen content in the ethanol and diethyl ether mixture.

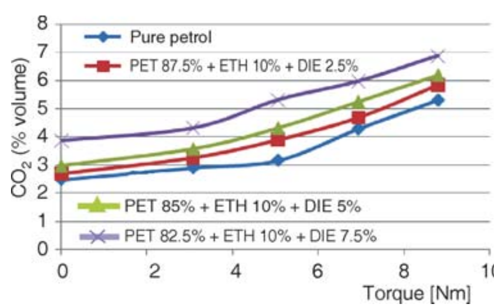

Figure 8. Variation of carbon dioxide with engine torque

Error analysis and uncertainty

Error is associated with various primary experimental measurements and the calculations of performance parameters. Errors and uncertainties in the experiments can arise from instrument selection, condition, calibration, environment, observation, reading, and test planning. Uncertainty analysis is needed to prove the accuracy of the experiments. The percentage uncertainties of various parameters like load and BTE were calculated using the percentage uncertainties of various instruments given in tab. 2.

Table 2. List of instruments and its range, accuracy and percentage uncertainties

No.	Instruments	Range	Accuracy	Percentage uncertainties
1	Gas analyzer	CO 0-10%, CO_2 0-20%, HC 0-10000 ppm.	+0.02% to –0.02% +0.03% to –0.03% +20 ppm to –20 ppm	+0.2 to –0.2 +0.15 to –0.15 +0.2 to –0.2 +0.2 to –0.2
2	Smoke level measuring instrument	NO_x 0-5000 ppm BSU* 0-10	+10 ppm to –10 ppm +0.1 to –0.1	+1 to –1
3	Exhaust gas temperature indicator	0-900 °C	+1 °C to –1 °C	+0.15 to –0.15
4	Speed measuring unit	0-1000 rpm	+10 rpm to –10 rpm	+0.1 to –0.1
5	Load indicator	0-100 kg	+0.1 kg to –0.1 kg	+0.2 to –0.2
6	Burette for fuel measurement		+0.1 cc to –0.1 cc	+1 to –1
7	Digital stop watch		+0.6 second to –0.6 second	+0.2 to –0.2
8	Manometer		+1 mm to –1 mm	+1 to –1
9	Pressure pickup	0-110 bar	+0.1 kg to –0.1 kg	+0.1 to –0.1
10	Crank angle encoder		+1° to –1°	+0.2 to –0.2

*BSU – Bosh smoke unit

Total percentage uncertainty

= Square root of {(uncertainty of total fuel consumption)^2 + (uncertainty of load)^2 + + (uncertainty of BTE)^2 + (uncertainty of CO)^2 + (uncertainty of unburned HC)^2 + (uncertainty of NO_x)^2 + (uncertainty of smoke number)^2 + (uncertainty of exhaust gas temperature)^2 + (uncertainty of pressure pickup)^2}

= square root of {(1) 2 + (0.2) 2 + (1) 2+ (0.2) 2+ (0.2) 2 + (0.2) 2+ (1) 2+ (0.15) 2 + + (1)2} = ±2.28%

The effect of ethanol and diethyl ether fuel blend percentage on HC emission is shown in fig. 7. It attributes the HC emission, whereby decreases in HC emission is observable when compared with pure petrol fuel for various blends. At full load condition the value of HC for diethyl ether blends (7.5%) was 155.5 ppm whereas for petrol it was about 185.5 ppm. Due to the complete combustion of the blends these emissions are decreased considerably. This effect is recognized because the stoichiometric air-fuel ratio of the ethanol and diethyl ether blends decreases and increase of actual air-fuel ratio of the ethanol and diethyl ether blends as a result of the oxygen content in the ethanol and diethyl ether mixture.

The errors associated with various measurements and in calculations of performances, parameters are computed in this section. The maximum possible errors in various measured parameters namely temperature, pressure, exhaust gas emissions, time and speed estimated from the minimum values of output and accuracy of the instrument are calculated using the method. This method is based on careful specification of the uncertainties in the various experimental measurements.

Conclusions

- Using diethyl ether and ethanol as a fuel additive to unleaded gasoline causes an improvement in engine performance and exhaust emissions.

- Diethyl ether addition results in an increase in brake power, BTE, volumetric efficiency, and fuel consumption by about 8.2%, 9%, 7%, and 5.7% mean average values, respectively. In addition, the brake specific fuel consumption decreases by about 2.4% mean average value.
- Using diethyl ether-unleaded gasoline blend leads to a significant reduction in exhaust emissions by about 26.5%, 24.3%, and 18.2% of the mean average values of CO, HC, and NO_x emission, respectively, for all engine torque. On the other hand carbon dioxide emission increases for all engine torque values.
- By adding the diethyl ether with gasoline the flame speed will increase, so that the spark timing of ethanol and diethyl ether blends has to be optimized. This may improve the performance.
- The peak pressure occurs in advance for diethyl ether blends compared pure gasoline. So spark timing has to be retarded. This may influence the performance characteristics.
- By adding the diethyl ether with pure gasoline with various percentages, the octane number of diethyl ether blends are increased due to highly volatile. This leads to use of higher compression ratio and hence higher power output. So, BTE of ethanol blends is also increased.

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