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Ethanol Fuelled SI Engine For The Measurement Of Acetaldehyde Emission

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Abstract— The Ethanol-gasoline blend is utilized in this work to measure the acetaldehyde (CH_3CHO) coming out from the engine exhaust using the alcohol/gasoline blends by the following method and to Characterize the aldehyde emission , study the performance characteristics, CO, HC, emission Levels in the Various blends.
Acetaldehyde can be sampled with the use of a standard miniature glass fibre filter coated with 3-methyl-2-benzothiazolinone hydrazone hydrochloride (MBTH).The absorption measurement is done immediately by using UV-visible spectrophotometer. Upon increasing the ethanol blend over petrol the readings were identified. On increasing Ethanol blend the PPM has been found to decrease at 85% ethanol at 100% load, 4.4 PPM has been noticed.
Keywords-Alchols, MBTH, UV-Visible Spectrophotometer

I. INTRODUCTION

A. Alcohol Fuels for S.I. Engines

In this century, it is believed that petroleum products will become very scarce and costly to find and produce. Increase in number of automobiles will lead to great demand for fuel in the near future. Gasoline and diesel will become scarce and most costly. Alternative fuel technology, availability, and use will become more common in the coming decades and considerable attention was focused on the development of alternative fuels, with particular reference to Alcohols. Among the various Alcohols, methanol (CH_3OH) and ethanol(C_2H_5OH) is considered to be the best blends with petroleum fuels or neat use in SI Engine. The use of alcohol fuels has demonstrated a path towards a cost-effective alternative to conventional gasoline engines and economical means of utilizing methanol or ethanol fuels. These alcohols can be readily made from a number of non-petroleum sources. Methanol or methyl alcohol (CH_3OH) can be produced from coal, a relatively abundant fossil fuel. Ethanol or ethyl alcohol (C_2H_5OH) can be produced by fermentation of carbohydrates which occur naturally and abundantly in some plants like corn and potatoes. Hence these fuels can be produced from highly reliable and long lasting raw material sources.

Alcohols were used in vehicles in the early part of this century, until low cost gasoline nearly forced them off the market. Racing cars have always preferred and continue to prefer methanol as a fuel because of the increased power obtainable from the same engine over gasoline. Methanol and ethanol make very good candidates for alternative fuels in that they are liquids and have several physical and combustion properties similar to gasoline and diesel fuel. Both ethanol and methanol have higher octane ratings than typical gasoline which allows alcohol engines to have much higher compression ratios, increasing thermal efficiency.

II. METHODS

Solution or blend-mixture of gasoline and alcohol.
Neat fuel mode-100% ethanol or methanol.
Feedstock for ethers.

III. SOLUTION

E85-85%ethanol & 15%gasoline
Flexible fuel vehicle-E0 to E85
Gasohol-10% ethanol by volume with gasoline.

IV. NEED FOR THE PROJECT

Aldehyde emissions that are coming out of the Engine exhaust, which are harmful gases to human health causes irritation of eyes and may cause headaches, general discomfort and irritability. There are reports of asthma caused by respiratory tract irritation due to formaldehyde exposure. Additionally they can cause potential harm to flora , including potherbs, and fauna, especially unicellular organisms that are relatively sensitive to formaldehydes. It can be involved in chemical reactions in the atmosphere, generating other compounds. Among them the photochemical Smog formation that mostly produces oxidizing gases, especially gas ozone.

Besides causing respiratory conditions to human beings, oxidizing gases can also damage materials, mainly rubbers. Thus it is very necessary to know the measurement level of Aldehyde and to reduce Aldehyde emissions in the exhaust of alcohol fuelled S.I. Engine.

V. OVERVIEW OF THE PROJECT

This project deals with the characterization of formaldehyde and acetaldehyde emissions in the alcohol fuelled S.I. Engine. The variable compression ratio petrol engine with a capacity of 2.5 kw @ 3000 rpm. The Engine testing with various alcohol blends with gasoline for various loads (0-100%) was carried out on a Eddy current dynamometer. High volume sampler were used for collecting the Aldehyde from the exhaust by placing the MBTH Coated filter paper inside the sampler and the absorbance of the sample was immediately measured in the U-V Spectrophotometer at 628 nm for formaldehyde and 612 nm for acetaldehyde. Horiba Automotive Emission Gas Analyzer MEXA 554J Series were used for measuring HC, CO and CO_2 emissions. NO_X Analyzers were used for measuring NO_X emissions.

Octane number (ON): Octane number of a fuel can be defined as the percentage by volume of iso-octane in a mixture of iso-octane and n-heptane.

Cetane number (CN): Cetane number of a fuel is defined as the percentage by volume of cetane in a mixture of cetane and a-methylnapthalene ($C_{10}H_7CH_3$).

CN= (104-ON) / 2.75

Fuel Property	Gasoline	Ethanol
Chemical formula	$mc_n H_{2n}$	C_2H_5 OH
Molecular Weight	112	46.0
Composition by Weight-%, Carbon	84.0	52.0
Hydrogen	16.0	13.0
Oxygen	nil	35.0
Specific gravity at 15.5°C	0.7 to 0.75	0.794
Boiling point °C	30.0	78.0
Latent heat of vapourization kcal/kg	70-100	204.0
Vapour pressure at 58°C	0.8	0.21
Lower calorific value kcal/kg	10, 500	6400
Stoichiometric Air/Fuel ratio	1417	9.0
Self ignition temperature °C	300-450	420
Motor octane number	82	94
Cetane number	-	-

Table .1 Important properties of gasoline and ethanol

VI. EXPERIMENTAL PROGRAMME

A. *Preparation of Filter Paper*

A 50 $\mu\ell$ aliquot of 0.5% MBTH solution was transferred to a Gelman type AE 13mm diameter glass fibre filter. The filters were then allowed to dry under vacuum for 30 min and stored in a closed brown bottle, placed in a desiccators.

B. *Preparation of Reagents*

1) *Preparation of MBTH Solution:* MBTH- 3-Methyl -2-Benzothiazolinone Hydrozone Hydrochloride Absorbing Solution

(0.05%). Dissolve 0.050g of MBTH in distilled water and dilute to 100 ml. It is stable for atleast 1 week after which it becomes pale yellow.

2) *Preparation of oxidizing Reagent:* Dissolve 1.6g of sulphamic acid(NH_2SO_3H) and 1.0g of ferric chloride($Fecl_3.6H_2O$) in distilled water and dilute to 100ml.

C. Instrumentation

Absorption measurements were performed on a UV-Visible Spectrophotometer.The basic methodology for sampling acetaldehyde produced from the combustion of ethanol in S.I engine exhaust includes the use of a standard miniature glass fibre filter coated with 3-methyl-2-benzothiazolinone hydrazone hydrochloride (MBTH). The acetaldehyde hydrazone formed (i.e. the adduct of acetaldehyde (CH_3CHO)and MBTH) was desorbed from the filter with distilled water and then oxidized by an ferric chloride-sulfamic acid solution to form a blue cationic dye in acidic medium which can be subsequently determined by visible absorption at 628 nm.The amount of Acetaldehyde in the engine exhaust is measured at a flow rate of 15 lits/min.

The oxidizing reagent solution is prepared by adding 0.5 gm of ferric chloride hexahydrate and 0.8 gm of sulfamic acid in a 50 ml standard flask and diluted to50 ml with distilled water. All the chemicals used are of analytical reagent (AR) grade. The formaldehyde from the exhaust that is adsorbed on the MBTH coated glass fibre filter is desorbed from it by adding 2 ml of distilled water and then kept for 20 mins and after that 2 ml of oxidizing reagent is added and again kept for 20mins and then the bluish colour is developed and then the absorption measurement is done immediately by UV-visible spectrophotometer.

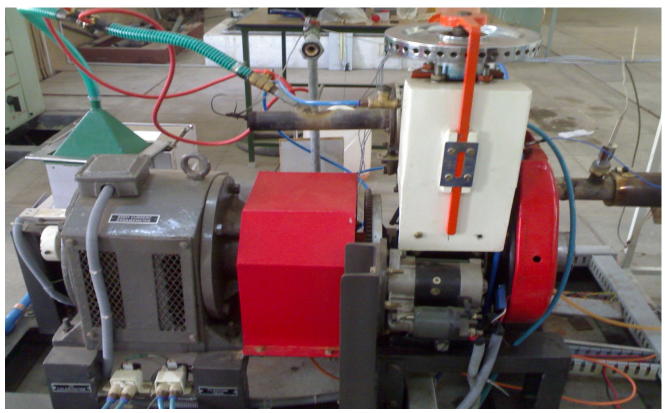

Figure 1 Schematic of the Engine test setup

The reaction scheme of the proposed method is shown in the next page:

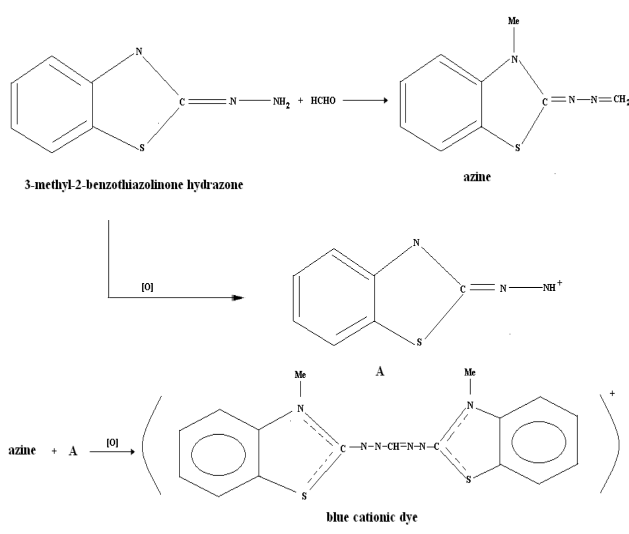

Figure 2.The reaction scheme

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This method provides a simple and reliable way of determining Aldehyde.

The boiling and condensation process for pure ammonia and ammonia-water mixture was shown in Fig.1. For pure ammonia the space between the source and working component is wide as ammonia boils and condenses at constant temperature. The gap between the working component and the source is reduced as compared with the pure ammonia. Due to varying boiling and condensation process this is achieved which makes it possible to utilize the energy efficiently form the source.

D. Experimental Setup

The experimental set up for this Aldehyde emission measurement purpose using methanol/ethanol-gasoline blends and 100% methanol consists of a high volume sampler that is placed near the engine exhaust. Above the high volume sampler a conical shaped apparatus made of CR sheet is prepared with a hole at the top. A hose pipe is connected between the exhaust tail-pipe and the top hole of the conical shaped apparatus. By this process the exhaust gas passes through the hose pipe and gets adsorbed on the MBTH coated

filter that is placed on the high volume sampler. Other all sides around the filter is covered by a rubber sheet so that all the exhaust gas gets coated on the filter only. The exhaust gas adsorbed filter is then immediately taken for measuring the absorption in UV-visible spectrophotometer. Figure 3 shows the schematic of the Engine test setup

1) Engine Specifications: Variable Compression Ratio Petrol Engine Test Rig Specifications:

ENGINE	4-STROKE,1-CYLINDER
MAKE	GREAVES
BHP	2.5Kw
RPM	3000 RPM
FUEL	*1)* ***PETROL***
BORE	70 mm
STROKE LENGTH	66.7mm
STARTING	SELF STARTER
METHOD OF IGNITION	SPARK IGNITION
ORIFICE DIA.	20mm
COMPRESSION RATIO	2.5 to 8
COOLING- BORE - HEAD	AIR COOLED, WATER COOLED
LOAD	EDDY CURRENT DYNAMOMETER
CAPACITY	2.5 kW
SPEED	3000 RPM

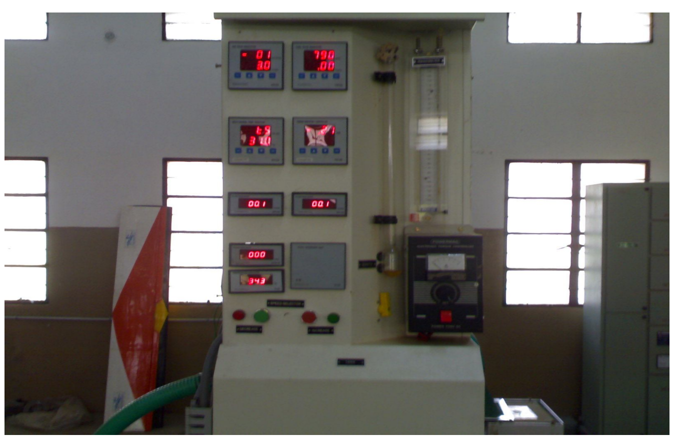

Figure3: Electronic meters

2) *Load cell for torque measurement:* A load cell is mounted on the loading end of the dynamometer, as the loading arm hits the load cell which sense the load and read out will be indicated in terms of torque(Nm) by the digital torque indicator. (Load cell capacity = 20 kg).

3) *Load cell arrangement for fuel flow measurement:* A fuel tank having a capacity of 4.5lt is mounted on a load cell (10kg) which helps measure the fuel rate. The loss in weight of the fuel is converted in to flow rate in kg/hr and is directly indicated on the digital fuel rate indicator and also a burette is connected parallelly as stand-by option.

4) *Air-rate measuring system:* An air tank is mounted below the control panel is connected to the air-rate indicator & also to the manometer across an orifice of 20mm diameter.

The manometric height is converted in to actual volume in m^3/hr and the same will be directly indicated on the air-rate indicator.

5) *Self start arrangement*

Figure 4 HORIBA Exhaust gas Analyzer

A Self starter is mounted perpendicular to the gear wheel, a self starter switch is mounted on the control panel which is connected across the battery is used for cranking the engine.

All the various readings of speed, torque, air flow rate, fuel mass flow rate and exhaust gas temperature are noted down from electronic meters fitted on the stand near the engine.

A HORIBA Exhaust gas analyser is also placed near the exhaust tail-pipe that is used to measure the HC, CO, CO_2 and lamda values. Electronic meters on a stand near the engine is fitted that gives the air flow rate, fuel flow rate, speed and torque values. A burette is also connected on the meter board that gives the rise and fall of fuel with respect to time. Figure 4 shows the horiba exhaust gas analyzer and Figure 3 shows the Electronic meters on a stand.

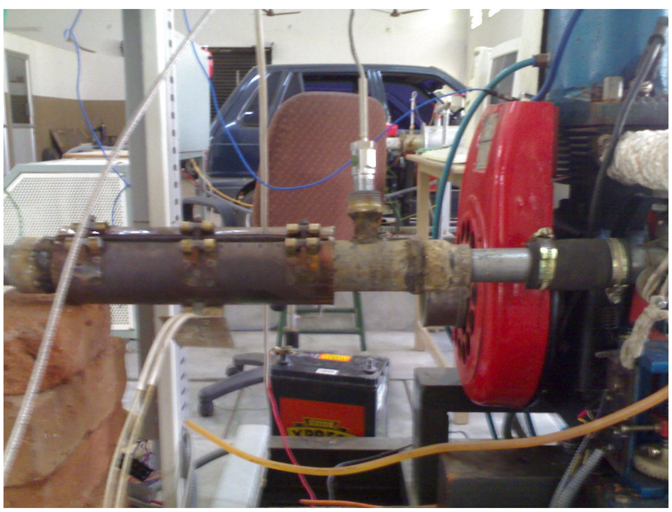

Figure 5. Heating Element Arrangement

For running the engine with alcohol-gasoline blends the jet diameter of the carburetor is increased so that more amount of fuel can

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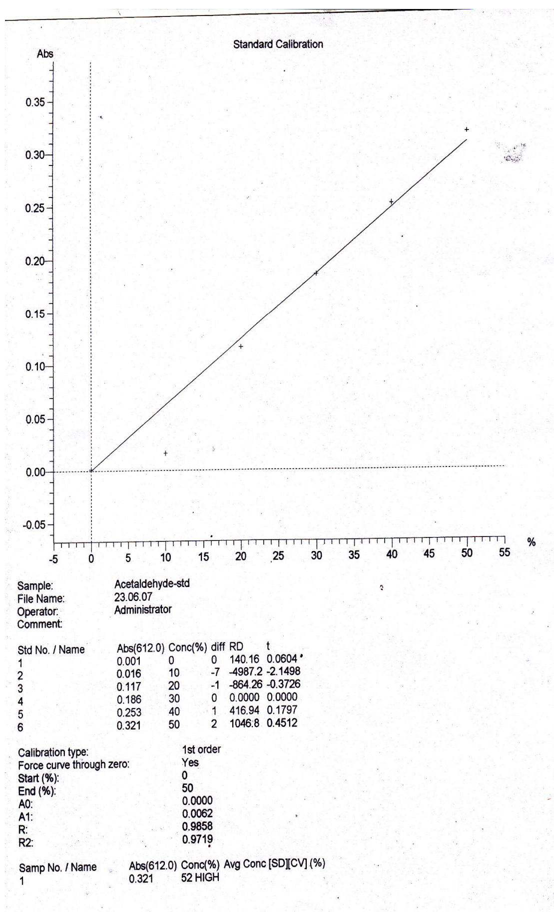
pass through it. The calorific value of alcohol is lower than gasoline, so to match the performance of engine running like gasoline, the supply of fuel has to be increased. Moreover, another set up is fabricated for heating the air before supplying to the carburetor. This includes a pipe that is clamped near the choke and around the pipe a electric heater is fitted that will heat the air. Figure 5 shows the heating element arrangement fitted before the inlet of the carburetor.

6) Preparation of stock Solution for Acetaldehyde: The standard solution is prepared by taking 0.56 ml of 30% acetaldehyde solution and then diluted to 100 ml having a concentration of 1000 ppm. From this solution 10 ml is taken in another 100 ml standard flask and diluted with distilled water to 100 ml mark. This made the concentration of formaldehyde solution to 100 ppm. This is the stock solution and to this solution 2 ml of oxidizing solution (0.5 gm ferric chloride hexahydrate& 0.8 gm sulfamic acid is added together and diluted to 100 ml with distilled water in a 100 ml standard flask) and 50 microlitres of 0.5% MBTH solution are added and this turned the stock solution to bluish colour. The absorption measurement of this stock solution is done immidiately at 628 nm using UV-visible spectrophotometer.

*7) **Preparation of standard solution for acetaldehyde:*** Five standard solutions of 10 ppm, 20 ppm, 30 ppm, 40 ppm and 50 ppm are prepared from the stock solution by appropriate quantity in a 25 ml standard flask and diluted to the mark with distilled water. The calculations for that are as follows:

Acetaldehyde (CH_3CHO)
Molecular Weight = 44.05
Density = 0.785g/ml
Mass/Volume = density
44.05/0.785 = 0.56ml/litre



Sample: Acetaldehyde-std
File Name: 23.06.07
Operator: Administrator
Comment:

Std No. / Name	Abs(612.0)	Conc(%)	diff	RD	t
1	0.001	0	0	140.16	0.0604
2	0.016	10	-7	-4987.2	-2.1498
3	0.117	20	-1	-864.26	-0.3726
4	0.186	30	0	0.0000	0.0000
5	0.253	40	1	416.94	0.1797
6	0.321	50	2	1046.8	0.4512

Calibration type: 1st order
Force curve through zero: Yes
Start (%): 0
End (%): 50
A0: 0.0000
A1: 0.0062
R: 0.9858
R2: 0.9719

Samp No. / Name	Abs(612.0)	Conc(%)	Avg Conc [SD][CV] (%)
1	0.321	52 HIGH	

Figure.6 Acetaldehyde standard calibration

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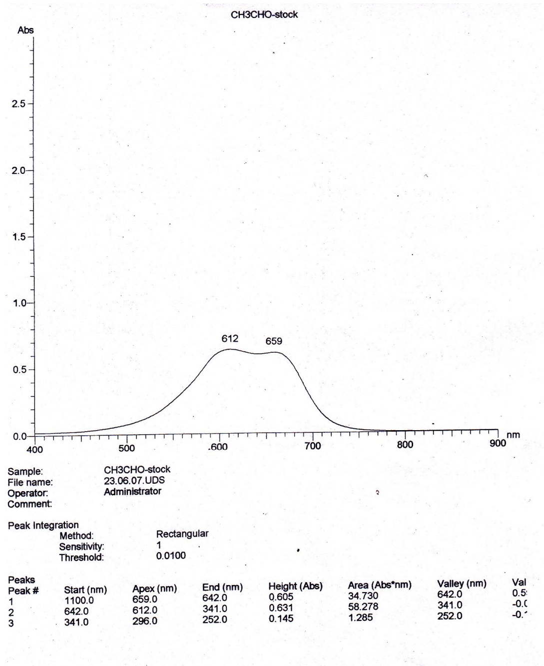

Figure.7 CH_3CHO Stock Analysis in UV-Spectrophotometer

The analysis in UV-Spectrophotometer is done by using sample cuvettes.

A. The first step in this analysis work involves the measurement of the absorbance of the stock solution (100 ppm). The Wavelength at which the stock solution gives maximum absorbance is noted.
B. Then the standard solutions of 20 ppm, 30ppm and 40 ppm are prepared from the
C. stock solution and their absorbance is noted at that particular wavelength of the maximum absorbance of the stock solution.
D. From this absorbance of the three standard solutions , a standard curve is prepared. The curve is a linearly increasing straight line with absorbance along the Y-axis and concentration (ppm) along the X-axis.
E. Then the blank solution (i.e. 50 micro lits of 0.5% MBTH solution + 2ml of oxidizing reagent solution + 2ml of distilled water) is prepared and their absorbance is measured in the wavelength range of 400 nm to 800 nm. This is called as base line correction. After this the sample solution of the engine exhaust is kept in the cuvette and the maximum absorbance at the particular wavelength is measured. The maximum absorbance is found to be around 628 nm . since both the standard , stock and the sample solutions are having bluish colour.
F. From that maximum absorbance of the sample solution the corresponding concentration is measured manually from the standard curve.
G. The software used for this measurement work is UV Solutions.

Figure 8(a) shows the Schematic of UV-Spectrophotometer with cuvettes and Figure 8(b) shows the UV-Spectrophotometer.

Figure.8 (a) UV-Spectrophotometer with cuvettes

Figure.8(b) Schematic of UV-Spectrophotometer

Fuel: 50% Ethanol + 50% Gasoline

Compression Ratio: 8:1

Ambient Temp: 30^{o}C

S.No	Load (%)	Torque (Nm)	Brake Power (KW)	Fuel Rate (Kg/Sec) x 10^{-4}	Air Flow Rate (m^3/hr)	Exh. Gas Temp. ()	HC (PPM)	CO (%Vol)	CO_2 (%Vol)	Lamda	NO_x	Speed (RPM)
1.	0	0	0	14	5.2	338	318	1.68	3.72	1.38	5	3100
2.	25	1.95	0.62	16	6.1	380	259	1.48	4.49	1.38	25	3045
3.	50	3.95	1.28	18	7.9	408	138	0.99	4.96	1.35	30	3097
4.	75	5.92	1.79	22	8	533	114	0.87	5.11	1.23	33	2900
5.	100	7.9	2.31	24	8.5	542	100	0.75	9.88	1.05	46	2800

Table.2 Readings with M50

Fuel: 85% Ethanol + 15% Gasoline

Compression Ratio: 8:1

Ambient Temp: 30^{o}C

S.No	Load (%)	Torque (Nm)	Brake Power (KW)	Fuel Rate (Kg/Sec) x 10^{-4}	Air Flow Rate (m^3/hr)	Exh. Gas Temp. ()	HC (PPM)	CO (%Vol)	CO_2 (%Vol)	Lamda	Speed (RPM)
1.	0	0	0	2.38	3	458	739	4.04	3.56	1.2	2750
2.	25	1.95	0.687	3.19	6.1	464	522	2.615	4.86	1.32	2770
3.	50	3.95	1.392	3.57	5.2	522	273	1.824	5.983	1.227	2800
4.	75	5.92	2.17	4.05	7.3	542	186	1.642	6.864	1.641	2912
5.	100	7.9	2.88	4.33	9.2	574	39	0.056	7.036	1.122	2900

Table.3 Readings with E85

S.NO.	Load(%)	Concentration(ppm)	Absorbance
1.	0	2.9	0.082
2.	25	3.4	0.136
3.	50	3.8	0.214
4.	75	4.1	0.219
5.	100	4.4	0.226

Table 4 Concentration of acetaldehyde emission (ppm) by using 85% Ethanol

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S.NO.	Load(%)	Concentration(ppm)	Absorbance
1.	0	1.6	0.103
2.	25	2.0	0.127
3.	50	2.5	0.156
4.	75	2.7	0.169
5.	100	4.1	0.255

Table 5 Concentration of acetaldehyde emission (ppm) by using 50% Ethanol

VII. RESULTS AND DISCUSSIONS

Ethanol-gasoline blends

Variation of CO Emission with load

Figure 9 shows that the CO emission is reducing with increase of load from 0 to 100% and for the E85 and E100 blends, the CO emission level is much lower than the other blends.

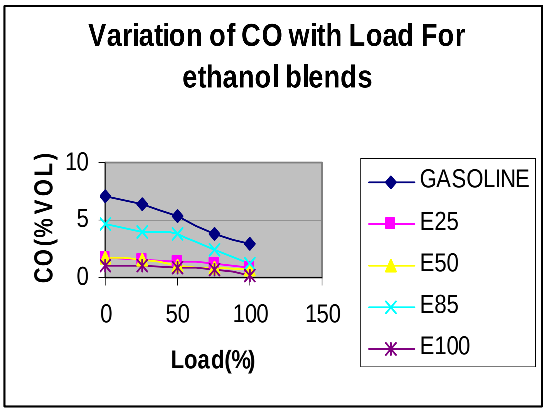

Figure 9. Variation of CO with load

Variation of NO_X Emission with Load

In the Figure 10. it is clear that NO_X increases with increase of varying loads for E25 and E50 blends whereas it is lower and has a straight line path along the X axis for E85 AND E100 Blends.

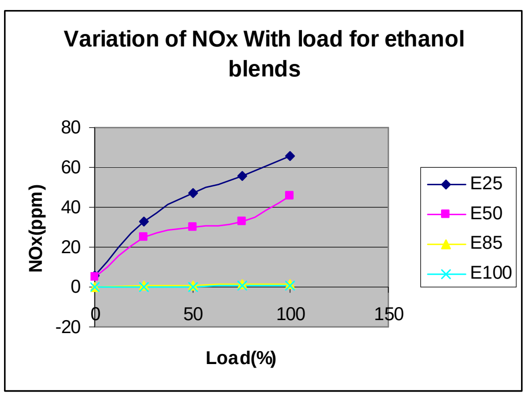

Figure 10. Variation of NOx with load

Variation of CO_2 Emission with Load

Figure Shows that an increase in CO_2 emissions with the increase in load from 0 to 100%. The exhaust gas temperature has also increased as long as the engine ran with the increase in load. The speed of the engine was kept in the range of 2500 to 3000 rpm.

VIII. CONCLUSION

From the experiments conducted, Ethanol as an alternative fuel in the S.I. Engine, we can conclude that alcohol fuel blends with gasoline is one of the best alternative fuel for S.I. Engine. It has good octane rating and is very volatile which the essential

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requirements for a S.I. Engine fuel are. It reduces the emission of HC and CO and it is less harmful to the environment than gasoline.

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