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Performance and Emission Analysis of a Spark Ignition, 4-Stroke, Single Cylinder IC Engine Using Different Ethanol Blends

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***Abstract**: The purpose of this study is to investigate experimentally and compare the engine performance and pollutant emission of a SI engine using different percentage of ethanol as additive to gasoline. Decrease in calorific value results in higher consumption of fuel for ethanol-gasoline blend as compared to petrol. The brake thermal efficiency, torque, power increase with increase in percentage of additive. E40 gave the best result for all measured parameters at all engine loads. E40 has good thermal efficiency at higher loads. As we increase the percentage of Ethanol in fuel, Specific fuel consumption increases. This is due to the lower heating value of ethanol compared with gasoline. As a result of improved combustion, reduction in CO, NOx and HC emission and Exhaust temperature while increase in CO_2 emission. HC and CO emission reduced for all the blends because of better combustion CO gets converted in to CO_2 and hence CO_2 emission increases.*

I. INTRODUCTION

Automobile have become a very important part of our modern life style. But the future of automobile based on internal combustion engines has been badly affected by two major problems. That is less availability of fuel and environmental degradation. So it is very important to found some new renewable non polluting alternative fuels to ensure the proper and safe survival of internal combustion engines.

Today, the transport sector is a major contributor to net emissions of greenhouse gases, of which carbon dioxide is particularly important. In Sweden this sector accounts for roughly 20 % of total energy consumption, and almost 50 % of the total net emissions of carbon dioxide. The carbon dioxide emissions originate mainly from the use of fossil fuels; mostly gasoline and diesel oil in road transportation systems, although some originates from other types of fossil fuels such as natural gas and Liquefied Petroleum Gas.

Today, ethanol accounts for a substantial part of the alternative fuel market, especially in Brazil, the USA and Sweden. The advantages of ethanol are that it can:

- Provide a viable alternative to reduce the greenhouse effect.
- Be produced domestically, thereby reducing dependence on imported petroleum.
- Be easily mixed with gasoline.
- Be used (and already is on a wide scale) as an oxygenate in gasoline.
- Create new jobs in the country related to its production.

1.1 current scenario of energy consumption:-

- Proved non-renewable petroleum resources are estimated to last till 2049 and available natural gas resources till 2070.
- Half of the petroleum or 20% of the total energy is being consumed by 550 million automobiles.
- CO emission will increase by 65% over the current level till 2010
- Earth temperature has increased by 3.5 deg. Centigrade from 1630.

II. ETHANOL GASOLINE BLENDS USED

In the United States ethanol is primarily produced from corn. Ethanol is denatured at the ethanol plant to prevent ingestion. The denaturing agent most often used is some type of hydrocarbon such as gasoline. Denatured ethanol may contain 2 to 15 percent gasoline, making it an ethanol and gasoline fuel blend. For example, E85 contains 85 percent ethanol and 15 percent gasoline. Other blends may include E10, which contains 10 percent ethanol and 90 percent gasoline, and E15, which contains 15 percent ethanol and 85 percent gasoline.

- E0: Pure Gasoline.
- E10: It contains 10% ethanol and 90% gasoline by volume.
- E20: It contains 20% ethanol and 80%gasoline by volume.
- E40: It contains 40% ethanol and 60% gasoline by volume.
- E60: It contains 60% ethanol and 40% gasoline by volume.
- E80: It contains 80% ethanol and 20% gasoline by volume.

- E100: 100% ethanol.

III. TEST METHOD

There are a few experimental steps in achieving the result. These are:-

- Prepare the composition blend of ethanol gasoline oil.
- Run the engine at 2500 r.p.m.
- Note down the readings.
- Determine the engine performance and emission analysis.

3.1Blending of ethanol & gasoline:

Ethanol & gasoline can be blended and used in many different concentrations, according to requirements. An experimental investigation has been carried out to analyze the performance characteristics and emission characteristics of a SI engine from the blended fuel (E0, E10, E20, E40, E60, E80, E100).

S.No.	Sample Code	Flash Point (^{0}C)	Auto Ignition Temp (^{0}c)	Density (Kg/m^3)	Calorific Value (KJ/Kg)	Octane No.	Specific Gravity
1	E0	-65	246	746	44000	91	0.746
2	E10	-35	261	749.9	42550	92	0.7499
3	E20	-20	279	753.8	41100	94	0.7538
4	E40	-13.5	294	761.6	38200	97	0.7616
5	E60	-1	345	769.4	35300	100	0.7694
6	E80	5	362	777.2	32400	104	0.7772
7	E100	125	365	785	29500	129	0.785

Table 3.1: Properties of Gasoline and Gasoline & Ethanol Blends

3.2experimental setup and measurement:

A 4 stroke single cylinder Petrol engine is used for the performance and emission analysis using ethanol blends with gasoline. At very first all different blends were prepared in laboratory and the engine was started and test were performed at constant speed and varying loads for each individual blends. Before testing with new blend the engine was allowed to run for sufficient time to consume the whole remaining fuel from previous blending. For getting an average value of result from each blending the test were performed four times for each mixture. The fuel consumption is measured via metred measuring jar. The consumption is measured for certain interval of time so that we can found the fuel consumption with respect to time. The same process is repeated for blends of E-0(pure gasoline), E-10, E-20, E-40, E-60, E-80, E-100 (Pure ethanol). Values of torque, power, total fuel consumption, brake specific fuel consumptions (BSFC), brake thermal efficiency (BTE) and Volumetric efficiency, while exhaust emissions were analyzed for CO, CO_2, Nox and HC by using different ethanol gasoline blends on volume basis and engine speed at 2500 rpm. The main focus of this study was to increase the performance and minimize the emission of four stroke petrol engine by using ethanol as additive with gasoline. The readings obtained from the conducted test have been evaluated and the result and graphs are compared compared with the pure gasoline.

3.3 engine specification:

BHP	3 HP
NO. of cylinders	One
Compression Ratio (C.R.)	4.5:1
Bore	67 mm
Stroke	56 mm
Type	Air Cooled
Air Drum Orifice	17 mm
Make	Honda
Speed (Max.)	3000 r.p.m.
Loading	Bulb Loading

3.4d.c. generator specification:

Make	Advent
Capacity	3 HP
Volts	220 DC
r.p.m	3000
Load in Amps	8.2 A

Fig3.1: Bulb Loading Arrangement

3.5exhaust gas analyzer:

An instrument used to analyze the chemical composition of the exhaust gas released by a engine. One type of analyzer measures the conductivity of the exhaust gas and indicates the ratio of fuel and air in the mixture that produced the exhaust gas.

Fig3.2: Exhaust Gas Analyzer

IV. RESULT & DISCUSSION

4.1engine performance analysis-

(a) Engine Performance Readings for E0 (Gasoline)-

Engine Load (w)	Voltage (v)	Current (A)	Fuel Consumed in 20 sec(ml)	Manometer Reading, h_w(mm)	Power Developed by Generator (w)	B.P. (w)	Torque (N-m)	Total Fuel Consumption (Kg/hr)	B.S.F.C. (Kg/KWh)	B.T.E. (%)	Vol. eff. (%)
No load	-	-	2.8	-	-	-	-	0.3759	-	-	-
500	122	2.8	3	5	341.6	488	1.864	0.4028	0.825	9.91	31.07
800	137	3.3	3.4	7	452.1	645.85	2.4669	0.4565	0.7077	11.56	36
1100	144	3.7	3.6	9	532.8	761.14	2.9073	0.4834	0.6352	12.88	41.68
1400	152	4.1	3.9	10	623.3	890.42	3.402	0.5236	0.588	13.91	43.9
1700	160	4.5	4.2	13	720	1028.5	3.928	0.5639	0.5482	14.92	50.1

(b)Engine Performance Readings for E10 -

Engine Load (w)	Voltage (v)	Current (A)	Fuel Consumed in 20 sec(ml)	Manometer Reading, h_w(mm)	Power Developed by Generator (w)	B.P. (w)	Torque (N-m)	Total Fuel Consumption (Kg/hr)	B.S.F.C. (Kg/KWh)	B.T.E. (%)	Vol. eff. (%)
No load	-	-	3	-	-	-	-	0.4049	-	-	-
500	124	2.9	3.2	6	359.6	513.71	1.962	0.4319	0.8407	10.06	34.03
800	140	3.4	3.6	8	476	680	2.597	0.4859	0.7145	11.84	39.3
1100	147	3.9	3.8	10	573.3	819	3.128	0.5129	0.6262	13.5	43.94
1400	154	4.1	3.9	12	631.4	902	3.445	0.5264	0.5836	14.49	48.13
1700	165	4.7	4.4	14	775.5	1107.8	4.232	0.5939	0.5361	15.78	51.99

(c) Engine Performance Readings for E20-

Engine Load (w)	Voltage (v)	Current (A)	Fuel Consumed in 20 sec(ml)	Manometer Reading, h_w(mm)	Power Developed by Generator (w)	B.P. (w)	Torque (N-m)	TotalFuel Consumption (Kg/hr)	B.S.F.C. (Kg/KWh)	B.T.E. (%)	Vol. eff. (%)
No load	-	-	3.1	-	-	-	-	0.4206	-	-	-
500	126	3	3.3	7	378	540	2.062	0.4477	0.829	10.56	36.76
800	143	3.4	3.7	10	486.2	694.57	2.653	0.5020	0.7228	12.11	43.94
1100	150	4	4	12	600	857.14	3.274	0.5427	0.6332	13.84	48.13
1400	159	4.2	4	13	667.8	954	3.644	0.5427	0.5688	15.39	50.1
1700	169	4.8	4.3	16	811.2	1158.8	4.426	0.5834	0.5034	17.39	55.58

(d)Engine Performance Readings for E40-

Engine Load (w)	Voltage (v)	Current (A)	Fuel Consumed in 20 sec(ml)	Manometer Reading, h_w(mm)	Power Developed by Generator (w)	B.P. (w)	Torque (N-m)	Total Fuel Consumption (Kg/hr)	B.S.F.C. (Kg/KWh)	B.T.E. (%)	Vol. eff. (%)
No load	-	-	3.3	-	-	-	-	0.4523	-	-	-
500	124	3	3.4	8	378	540	2.062	0.4661	0.9585	11.59	39.31
800	149	3.5	3.6	11	521.5	745	2.845	0.4935	0.7323	15.17	46.08
1100	157	4.2	4	14	659.4	942	3.598	0.5483	0.5939	18.7	51.99
1400	165	4.5	4.2	16	742.5	1060.7	4.0516	0.5757	0.54067	20.55	55.58
1700	169	4.8	4.4	20	811.2	1158.8	4.426	0.6032	0.5069	21.91	62.14

(e)Engine Performance Readings for E60 -

Engine Load (w)	Voltage (v)	Current (A)	Fuel Consumed in 20 sec(ml)	Manometer Reading, h_w(mm)	Power Developed by Generator (w)	B.P. (w)	Torque (N-m)	Total Fuel Consumption (Kg/hr)	B.S.F.C. (Kg/KWh)	B.T.E. (%)	Vol. eff. (%)
No load	-	-	3.4	-	-	-	-	0.4708	-	-	-
500	125	3	3.6	7	375	535.71	2.046	0.4985	0.9305	10.95	36.76
800	144	3.4	3.5	9	489.6	699.43	2.672	0.4718	0.6745	15.71	41.68
1100	154	4.1	3.7	12	631.4	902	3.445	0.5124	0.5681	17.95	48.13

1400	160	4.4	3.9	14	704	1005.7	3.8415	0.5401	0.5371	18.99	51.99
1700	168	4.9	4.1	17	823.2	1176	4.492	0.5678	0.4828	21.12	57.29

(f)Engine Performance Readings for E80 -

Engine Load (w)	Voltage (v)	Current (A)	Fuel Consumed in 20 sec(ml)	Manometer Reading, h_w(mm)	Power Developed by Generator (w)	B.P. (w)	Torque (N-m)	Total Fuel Consumption (Kg/hr)	B.S.F.C. (Kg/KWh)	B.T.E. (%)	Vol. eff. (%)
No load	-	-	3.5	-	-	-	-	0.4896	-	-	-
500	128	3.1	3.7	6	396.8	566.85	2.165	0.5176	0.8223	11.46	34.03
800	138	3.2	3.9	7	441.6	630.85	2.409	0.5456	0.6959	12.04	36.76
1100	149	3.9	4	9	581.1	830.14	3.171	0.5595	0.6039	14.26	41.68
1400	154	4.2	4.1	11	646.8	924	3.529	0.5735	0.5584	15.12	46.08
1700	163	4.8	4.2	14	782.4	1117.7	4.269	0.5875	0.4981	17.46	51.99

(g)Engine Performance Readings for E100 -

Engine Load (w)	Voltage (v)	Current (A)	Fuel Consumed in 20 sec(ml)	Manometer Reading, h_w(mm)	Power Developed by Generator (w)	B.P. (w)	Torque (N-m)	Total Fuel Consumption (Kg/hr)	B.S.F.C. (Kg/KWh)	B.T.E.	Vol. eff. (%)
No load	-	-	3.5	-	-	-	-	0.4945	-	-	-
500	126	3	3.9	8	378	540	2.062	0.5511	1.0205	11.95	39.32
800	140	3.2	4.2	9	448	640	2.445	0.5934	0.9273	13.16	41.68
1100	143	3.3	4.4	11	471.9	674.14	2.575	0.6217	0.923	13.23	46.08
1400	152	3.7	4.7	12	562.4	803.43	3.068	0.6641	0.826	14.76	48.13
1700	159	4.3	4.9	14	683.7	976.72	3.731	0.6924	0.7089	17.22	51.99

4.2 engine emission analysis-

(a) Engine Emission readings for E0(Gasolene) –

Engine Load(W)	CO (%) Vol.	HC (ppm)	CO_2 (%)Vol.	Nox (ppm)	ExhaustTemperature (°C)
No load	3.2	453	4	24.1	402
500	3.8	462	3.8	42.3	473
800	5.1	523	3.2	56.9	503
1100	6	673	2.9	89.7	568
1400	7.2	822	2.6	127.5	635
1700	8.4	923	2.5	176.9	723

(b) Engine Emission readings for E10 –

Engine Load(W)	CO (%) Vol.	HC (ppm)	CO_2 (%)Vol.	Nox (ppm)	ExhaustTemperature (°C)
No load	2.6	400	4.1	23.7	400
500	3.5	406	3.9	40.1	461
800	4.6	468	3.4	55	497
1100	5.7	516	3.6	87.9	532
1400	6.6	776	3.5	124.3	598
1700	7.3	816	3.9	155.8	688

(c) Engine Emission readings for E20 –

Engine Load(W)	CO (%) Vol.	HC (ppm)	CO_2 (%)Vol.	Nox (ppm)	ExhaustTemperature (°C)
No load	2	368	4.3	21.9	392
500	3.2	392	3.6	38	438
800	4.4	406	3.8	49.3	456
1100	5.2	475	3.7	80.1	501
1400	5.8	616	3.5	117.3	572

1700	6.7	736	3.8	151.9	648

(d) Engine Emission readings for E40 –

Engine Load(W)	CO (%) Vol.	HC (ppm)	CO_2 (%) Vol.	Nox (ppm)	ExhaustTemperature (°C)
No load	1.6	312	6	21.1	385
500	2.9	348	5.7	37.2	407
800	4.1	379	5.9	45.9	428
1100	4.8	419	5.1	77.3	480
1400	5.5	573	4.7	111	526
1700	6.3	689	4.5	148.1	599

(e) Engine Emission readings for E60 –

Engine Load(W)	CO (%) Vol.	HC (ppm)	CO_2 (%)Vol.	Nox (ppm)	ExhaustTemperature (°C)
No load	1.1	296	8.1	20	372
500	2.6	319	7.9	34.7	397
800	3.8	342	8.3	41.7	418
1100	4.3	393	7.8	69.3	455
1400	4.9	499	7.6	103	503
1700	5.6	616	7.2	135.2	536

(f) Engine Emission readings for E80 –

Engine Load(W)	CO (%) Vol.	HC (ppm)	CO_2 (%)Vol.	Nox (ppm)	ExhaustTemperature (°C)
No load	0.7	252	9.3	18.7	290
500	2.5	285	9	30	324
800	3.1	314	8.8	37.1	365
1100	3.6	363	8.4	57.9	390
1400	4.5	446	8	92	426
1700	5.3	592	7.8	123.7	461

(g) Engine Emission readings for E100 –

Engine Load(W)	CO (%) Vol.	HC (ppm)	CO_2 (%)Vol.	Nox (ppm)	ExhaustTemperature (°C)
No load	0.5	236	10.9	15.3	212
500	2.3	264	11.2	27.1	231
800	2.7	300	11.8	33.9	278
1100	3.2	336	12.3	50.1	299
1400	3.9	401	11.5	78.3	322
1700	4.7	502	11.2	107.3	341

4.3 performance & emission analysis curves:

4.3.1 Effect on Power:

Fig4.1 shows the Effect of the ethanol fuel blending on engine power. Theengine power is increased as the volume percentage of ethanol fuel is increased in the fuel mixture to E80.

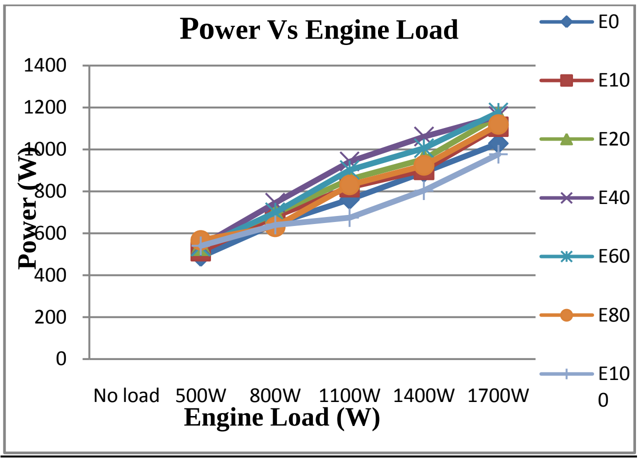

Fig4.1: Graph between Power Vs Engine Load

4.3.2 Effect on Torque:

Fig4.2 shows the Effect of the ethanol fuel blending on torque. The torque is increased as the volume percentage of ethanol fuel is increased in the fuel mixture to E80.

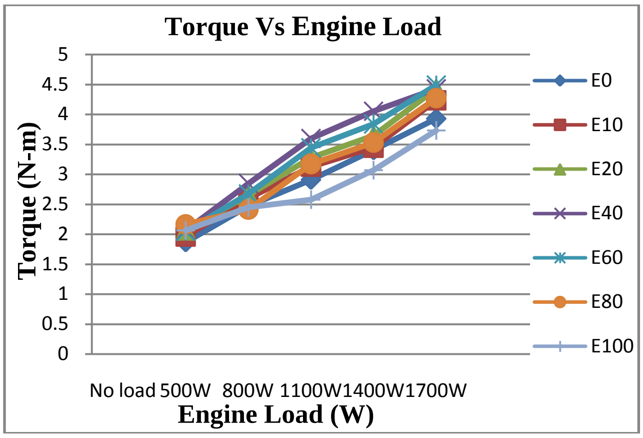

Fig4.2: Graph between Torque Vs Engine Load

4.3.3 Effect on Total Fuel Consumption:

Figure 4.3 shows the effect of the ethanol fuel blending on the total fuel consumption (T.F.C). The T.F.C is s increased as the volume percentage of ethanol fuel is increased in the mixture. This is due to the lower heating value of ethanol compared with gasoline.

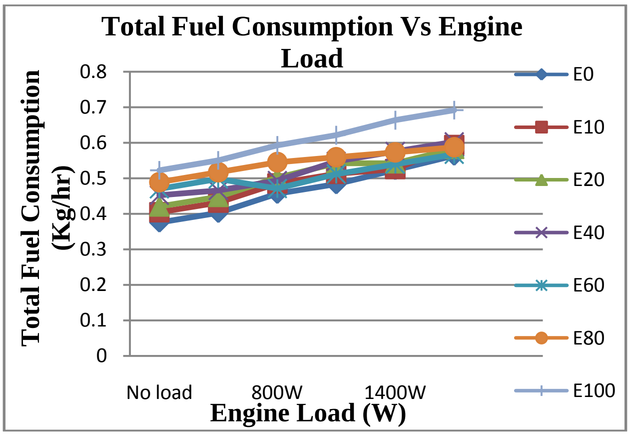

Fig4.3: Graph between Total Fuel Consumption Vs Engine Load

4.3.4 Effect on Brake Specific Fuel Consumption:

The variation of B.S.F.C. with engine load for different percentage of Ethanol with the gasoline as shown in Fig4.4. The additive of Ethanol shows slightly higher B.S.F.C compare to gasoline. This behavior is attributed to the lower heating value per unit mass of the Ethanol fuel, which is distinctly lower than that of the gasoline 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 fuel. The BSFC decreases with the increasing loads. It is inversely proportional to the thermal efficiency of the engine.

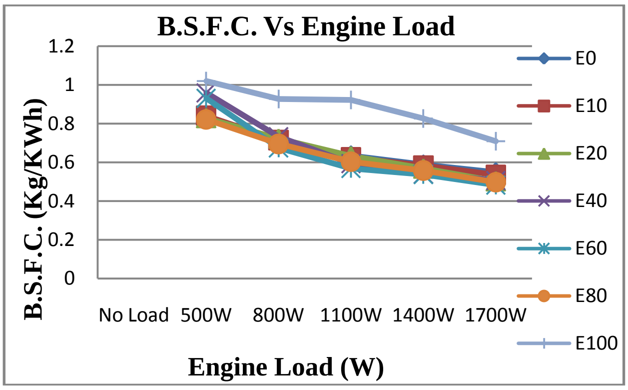

Fig4.4: Graph between B.S.F.C. Vs Engine Load

4.3.5 Effect on Brake Thermal Efficiency:

The variation of B.T.E with brake power for different percentage of additives of Ethanol with the gasoline as shown in Fig4.5. The additive of Ethanol shows The B.T.E is higher than the gasoline. The BTE is higher for various additives because of improve combustion efficiency. The brake thermal efficiency is based on B.P and calorific value. of the engine . Brake thermal efficiency gradually increases with increase in percentage of additives. It is observed that brake thermal efficiency is low at low values of B.P and is increasing with increase of B.P for all additives of fuel.

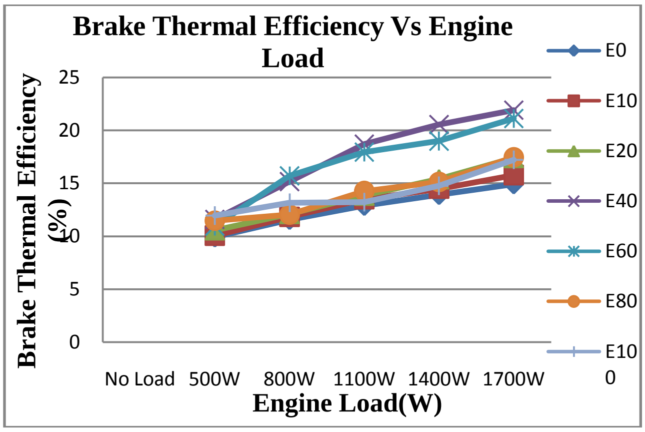

Fig4.5: Graph between Brake Thermal efficiency Vs Engine Load

4.3.6 Effect on Volumetric Efficiency:

The variation of Volumetric efficiency with engine load for different percentage of additives of Ethanol with the gasoline as shown in Fig 4.6. The additive of Ethanol shows the Volumetric efficiency is higher than the gasoline.

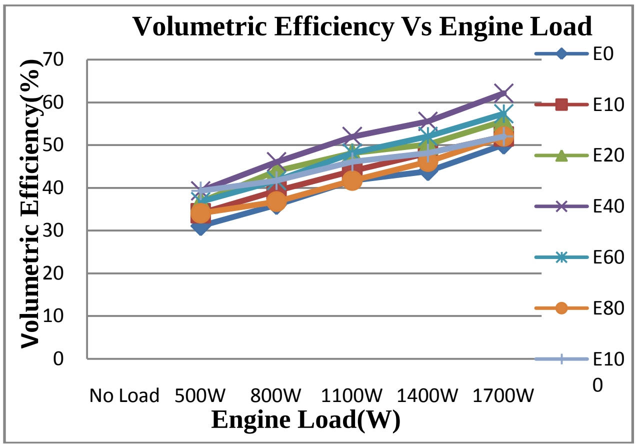

Fig4.6: Graph between Volumetric efficiency Vs Engine Load

4.3.7 Effect on Carbon monoxide (CO) Emission:

It is a product of incomplete combustion due to insufficient amount of air in the air- fuel mixture. When Ethanol containing oxygen is mixed with gasoline, the combustion of the engine becomes better and therefore, CO emission is reduced. Fig4.7 shows the Effect of the ethanol fuel blending on CO emissions. The concentration of CO is decreased as the volume percentage of ethanol fuel is increased in the fuel mixture. This is due to the reduction in carbon atoms concentration in the blended fuel and the high molecular diffusivity and high flammability limits which improve mixing process and hence combustion efficiency.

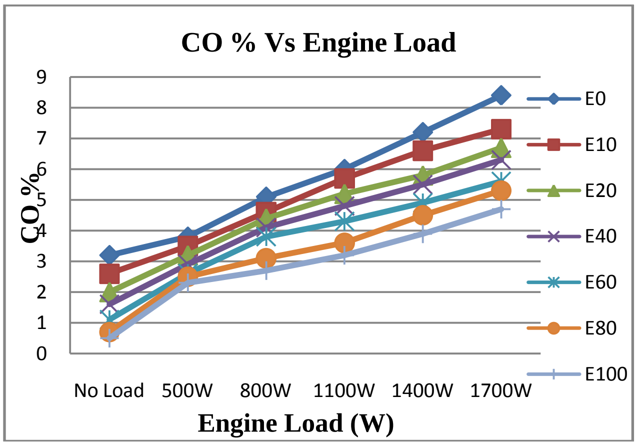

Fig4.7: Graph between Carbon monoxide emissions Vs Engine Load

4.3.8 Effect on Hydrocarbon (HC) Emission:

Rich air fuel ratio with insufficient oxygen prompts the incomplete combustion of fuel as a misfire produces the unburnt hydrocarbon. When ethanol is added to the blended fuel, it can provide more oxygen for the combustion process and leads to the so-called "leaning effect". This indicates that the engine tends to operate in leaner conditions, closer to stoichiometric burning as the ethanol content is increased. Its final result is that better combustion can be achieved therefore the concentration of HC emission decrease as the ethanol content increase.

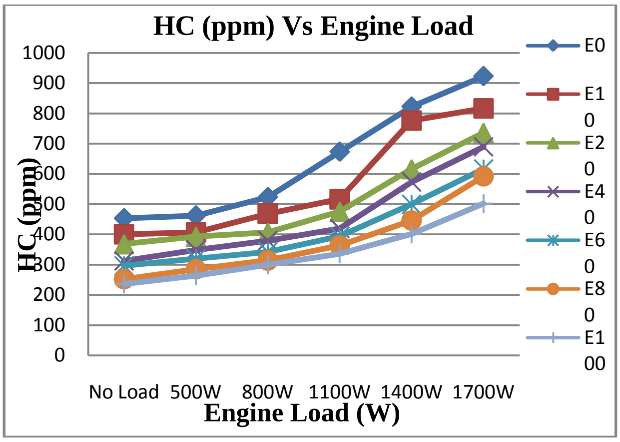

Fig4.8: Graph between HC ppm Vs Engine Load

4.3.9 Effect on Carbon dioxide (CO_2) Emission:

Fig4.9 shows the Effect of the ethanol fuel blending on CO_2 emissions. The concentration of CO_2 is increased as the volume percentage of ethanol fuel is increased in the fuel mixture.

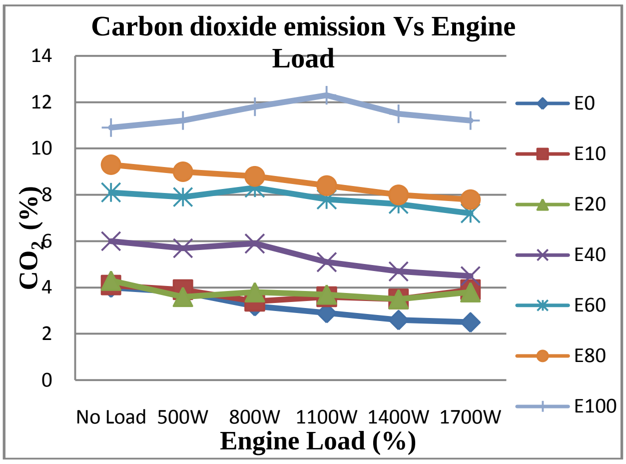

Fig4.9: Graph between Carbon dioxide emissions Vs Engine Load

4.3.10 Effect on Nitrogen oxide (Nox) Emission:

When Ethanol containing oxygen is mixed with gasoline, the combustion of the engine becomes better and therefore, Nox emission is reduced. Fig4.10 shows the Effect of the ethanol fuel blending on Nox emissions. The concentration of Nox is decreased as the volume percentage of ethanol fuel is increased in the fuel mixture. When the engine condition goes leaner, the combustion process is more complete and the concentration of Nox emission gets lower.

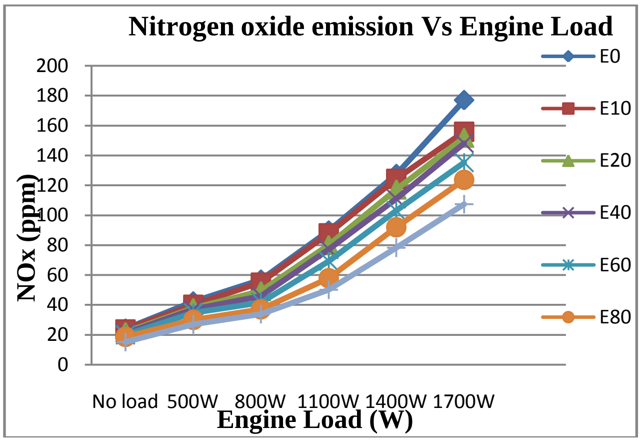

Fig4.10: Graph between Nitrogen oxide emissionVs Engine Load

4.3.11 Effect on Exhaust Temperature (^oC):

When ethanol percentage increase exhausts gas temperature decrease shown in Fig 4.11. Exhaust gas temperature is the function of combustion temperature and the temperature of the combustion is depends upon the heating value of the fuel. Heating value of the ethanol is less compared to the gasoline, therefore with the increase of ethanol percentage the combustion temperature decrease as result is exhaust gas temperature decrease.

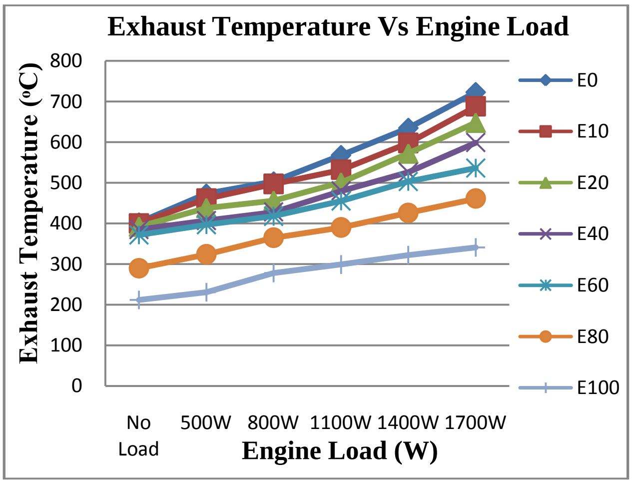

Fig4.11: Graph between Exhaust temperatures Vs Engine Load

V. CONCLUSION

Experiments have been conducted on single cylinder four stroke petrol engine with different percentage of ethanol as additive to gasoline. Decrease in calorific value results in higher consumption of fuel for ethanol-gasoline blend as compared to petrol. The brake thermal efficiency, torque, power increase with increase in percentage of additive.**E40 gave the best result for all measured parameters at all engine loads**. Thus ethanol may be used as an additive for gasoline in future. Brake Thermal Efficiency, is increased as the volume percentage of ethanol fuel is increased in the mixture. E40 has good thermal efficiency at higher loads. As we increase the percentage of Ethanol in fuel, Specific fuel consumption increases. This is due to the lower heating value of ethanol compared with gasoline.

As the ethanol contentin the blend increases, density of the mixture increases, which leads to increase in power and slightly specific fuel consumption. As a result of improved combustion, reduction in CO, NOx and HC emission and Exhaust temperature while increase in CO_2 emission. HC and CO emission reduced for all the blends because of better combustion CO gets converted in to CO_2 and hence CO_2 emission increases. In this study, we found that using ethanol–gasoline blend, CO emission may be reduced by 10–20%, while CO_2 emission increases by 10–15% depending on engine conditions. **Result shows that E40 is the best suitable blend.**

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