Analysis on Emissions of Gasoline Engine with Different Ethanol Blends at Different Compression Ratio

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Abstract: -

Alcohol fuels do have some extra benefit compare to other alternative fuels, like the capability to work in existing engines also have the ability to decrease harmful emissions. Among the various alcohols, ethanol is considered most appropriate fuels for SI engines, because of its superior fuel quality and ecological benefits. In this experiment, ethanol was blended in different ratios as 0%, 5%, 10% and 20% with gasoline. The effect of the ethanol/gasoline blends on engine emissions at various compression ratios (CRs) of 10:1, 10.5:1, 11:1 and 11.5:1 was studied and examine by using computerized single cylinder, 4 stroke, multi-fuel, variable CRs engine. Engine emission characteristics are studied experimentally by the combustion of different blends of E0, E5, E10 and E20 at different loads of 0 kg, 1 kg, 2 kg and 3 kg. Result shows that adding ethanol in gasoline engine at CRs of 10:1, 10.5:1, 11:1, and 11.5:1 emission reduces (CO, CO_2, NOx except HC). Additionally, CO_2 emissions were found lower in E0 at CR 10.5:1 and also at CR 11.5:1 as compared to E5, E10 and E20. Also, it was observed that blended fuel permits varying CRs without any knock occurrence. Finally, octane numbers are found to be higher with ethanol blends.

Keywords: - Ethanol, Octane Number, Combustion, Emissions, knock etc.

1. INTRODUCTION

The Current energy crisis, along with strict emission regulation have encouraged to search for find more alternative fuels that can replace traditional fossil fuels in countries all over the world [1]. Countries like as India, Brazil, United States, China, and other have implemented laws and regulations to promote the use of biofuels. Biofuel can help to maintain engine efficiency as well as limit the energy crisis within specified range and efficiently reduce polluting emissions, according to research. Biofuels, which are generated from agriculture products and oxygenated naturally, are present in the form of alcohols. Alcohols particularly methanol and ethanol have been proposed as alternative fuel for internal combustion SI engine [2,3]. Many researchers have been considered ethanol, a biomass-based renewable fuel to be one of the most important alternative fuels for gasoline engines since it can be made from renewable energy sources like sugarcane, corn, edible and non-edible feedstocks. Also, ethanol has a higher-octane number than gasoline, allowing it to be used at higher CRs in spark ignition engines. Additionally, ethanol has a higher flame speed than conventional fuels like gasoline and diesel, and it contains less carbon as a fuel, reducing harmful emissions significantly [4,5]. Many researchers experimentally Investigated the emission behaviour of a spark ignition engine running on pure petrol (E0) and different ethanol/gasoline mixtures like E10, E20, E30, E40, E50, E85 and E100. The results indicate that ethanol blends beyond E20 saturated hydrocarbon emissions increased. Blending ethanol into gasoline decreases exhaust engine emissions (CO, CO_2 NOx, HC and particulate matter) because pure ethanol has less carbon content than that of gasoline [6-9]. Iodice, P., et al. The cold emission characteristics of internal combustion engines fuelled by blended (ethanol/petrol) fuel was investigated, and the results show that HC and CO cold start emissions are decreased than when conventional gasoline is used. The highest emission reduction is achieved when using an E20 ethanol blend. [10]. Moreover, in this experimental analysis has been done on the emissive behaviour of internal combustion engines fuelled with blended (ethanol/petrol) fuels. In this present work, the engine emission was measured under a variety of engine operating conditions. With keeping in mind, the financial and environmental considerations an attempt has been made to enhance the emissions characteristics, satisfactory results were obtained and the work carried out is presented.

2. Experimental Setup: -

This Experimental setup comprises of a computerized single cylinder, 4 stroke, (Kirloskar) multi-fuel, variable compression ratio engine, Fig. 1 shows a systematic line diagram of engine setup and Table 1 shows the description of line diagram of engine setup. Test engine details are shown in Table 2. Details of AVL digas 444 gas analyzer are shown in Table 3. Dynamometer (eddy current type) was used to apply load. A scaled tube was used to measure fuel consumption with the help of stopwatch. The chemical and physical properties of ethanol-gasoline blends are shown in Table 4.

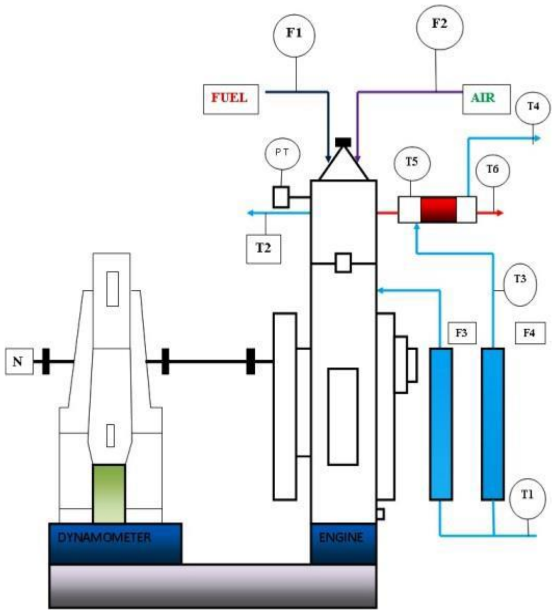

Figure 1 line diagram of engine setup

Table 1 Description of line diagram

F1	Consumption of Fuel (kg/hr)
F2	Consumption of air (kg/hr)
F3	Water flow to Engine (litre per hour)
F4	Water flow to calorimeter (lbh)
T1	Water inlet to jacket temperature (°C)
T2	Water outlet to jacket temperature (°C)
T3	Water inlet to Calorimeter temperature (°C)
T4	Water outlet to calorimeter temperature (°C)
T5	Inlet exhaust gas to calorimeter temperature (°C)
T6	Outlet exhaust gas from calorimeter temperature (°C)
PT	Cylinder pressure transducer (bar)
N	RPM Decoder

Table 2 ENGINE DETAILS	
Make	Kirloskar
Model	TV1
No. of Cylinder	Single
Connecting rod length	234 (mm)
Stoke	110 (mm)
Displacement	661(CC)
Bore	87.5 (mm)
Normal (CR)	17.5:1
Variable Compression Ratio	6:1 to 18:1 for petrol and Diesel
Rated output	5HP at 1500 (rpm)
Cooling type	Normal water
Starting type	Self-Start along with battery
Lubricant type	Forced
Output on petrol mode 6:1 to 9:1	5KW at 1500 to 1800 (rpm)
Output on Diesel mode 14:1 to 18:1	5 KW at 1500 (rpm)
Working fuel	Petrol/Diesel

Table 3 Exhaust Gas Analyser	
Brand	AVL
Model	Digas 444
Type	Pipe in Pipe
Display type	Digital
Measured value output	(CO, CO_2, HC, and NOx)

3. Experimental Procedure: -

1. Two litres of ethanol and gasoline mixture are prepared with various ratios of ethanol with gasoline, in the proportion as 0%, 5%, 10% and 20%, to achieve the mixture's steady-state and homogeneity, the mixture was given 30 min. time period. The mixture is now ready to use.
2. For comparison, the first test was carried out on pure gasoline (E0); after that, four tests were carried out with the ethanol-gasoline mixture against engine loads of 0 kg, 1 kg, 2 kg and 3kg at the constant engine speed of 1500 (rpm). Then similar test method was used for different compression ratios.
3. The engine's rotary speed was measured using an optical sensor pulse, and a constant engine speed of 1500 (rpm) was maintained throughout the test.
4. Exhaust emissions readings were differentiated and analysed by AVL digas 444 exhaust gas analyzer.
5. Consumption of fuel was calculated by recording the time (using stop watch) required by the gasoline/ethanol blends to pass through the scaled tube.

Table 4 Physical and chemical properties of ethanol/gasoline blend

S. No.	Fuel Blends	Pour Point °C	Fire Point °C	Flash Point °C	Stoichiometric ratio (A/F)	Density Kg/m3	Octane No.	Self-ignition Temp. °C	Boiling Point °C
1	E0	14	70	69	14.60	836	88	68	58
2	E5	13.5	68	67	14.20	832	94	64	55
3	E10	13	66	65	14.05	828	90	62	55
4	E20	12.5	65	64	13.50	826	88	59	50
5	E100	14	69	68	09.00	842	97	63	76

4. Results and Discussion

Emissions Characteristics

Engine emissions have been plotted based on the data collected from the AVL DIGAS 444 gas analyzer at different loads. In this research paper work important emissions from SI engine are discussed.

Load Vs CO

CO is produced when combustion of fuel is incomplete and also because of insufficient time of combustion. The variations of CO emissions versus engine loads of 0 kg, 1 kg, 2 kg and 3 kg have been shown in Figures 2, 3, 4 and 5. In the combustion of fuel, the carbon that is presented in fuel is converted into CO. At CR 10, maximum CO emissions are 0.18% at 0 kg load for E0, and minimum CO emissions are 0.05% at 0 kg load for E5. At CR 10.5, maximum CO emissions are 1.18% at 3 kg load for E0, and minimum CO emissions are 0.05% at 0 kg load for E0. At CR 11, maximum CO emissions are 0.13% at 0 kg load for E20, and minimum CO emissions are 0.06% at 1 kg load for E10. At CR 11.5, maximum CO emissions are 0.11% at 0 kg load for E0, and minimum CO emissions are 0.07% at 0 kg load for E5. Higher CO emissions at 0 kg load condition are observed because the engine requires a rich mixture at no-load condition (0 kg) to avoid exhaust gas dilution.

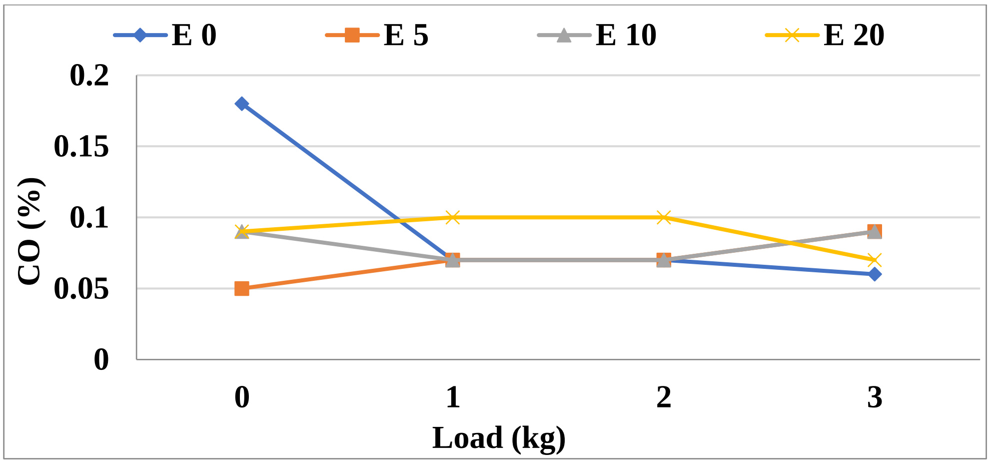

Figure 2 Load Vs CO at CR 10

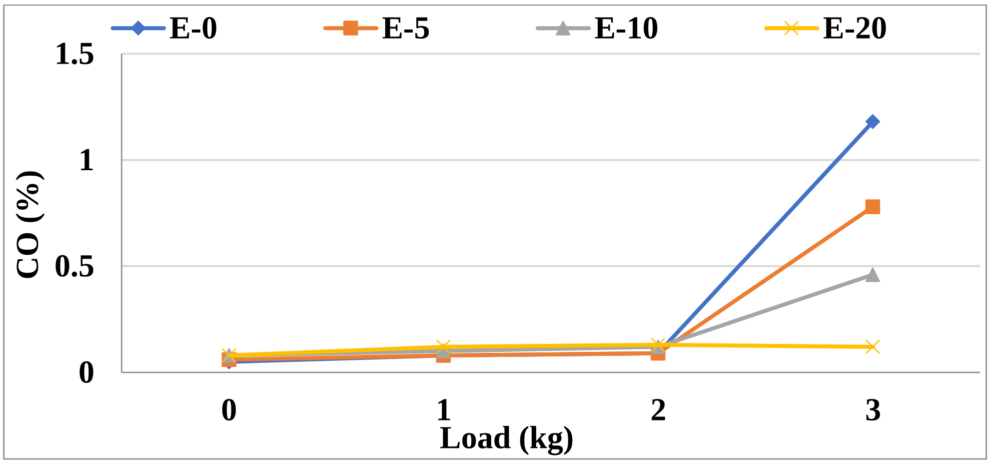

Figure 3 Load Vs CO at CR 10.5

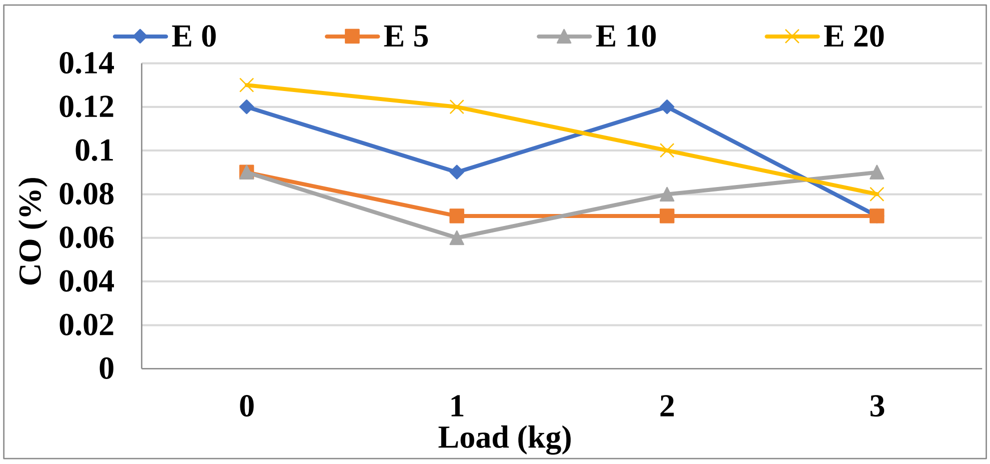

Figure 4 Load Vs CO at CR 11

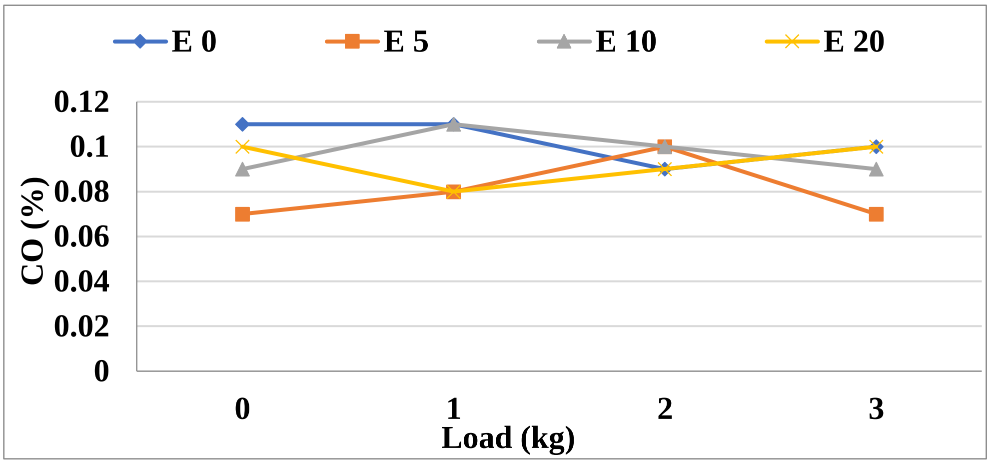

Figure 5 Load Vs CO at CR 11.5

Load Vs CO_2

The variations of CO_2 emissions versus engine loads have been shown in Fingers 6, 7, 8 and 9. CO_2 is formed when the fuel burns completely. Ethanol has less carbon contain compare to gasoline thus produces less CO_2. At CR 10, maximum CO_2 emissions are 11.06% at 0 kg load for E0, and minimum CO_2 emissions are 5.56% at 0 kg load for E5. At CR 10.5, maximum CO_2 emissions are 14.04% at 3 kg load for E10, and minimum CO_2 emissions are 4.05% at 0 kg load for E0. At CR 11, maximum CO_2 emissions are 12.29% at 0 kg load for E20, and minimum CO_2 emissions are 3.78% at 3 kg load for E0. At CR 11.5, maximum CO_2 emissions are 18.84% at 0 kg load for E10 and minimum CO_2 emissions are 3.97% at 3 kg load for E0. CO2 emissions are reduced when blended fuel is used, as can be observed. This is due to a low carbon/hydrogen ratio in the blended fuel, as well as the fact that it burns more effectively with a more homogeneous combination, resulting in lower CO_2 emissions when compared to pure gasoline (E0). CO_2 is formed when oxygen (O_2) is sufficient which causes higher CO_2 emissions at CR 10.5 and CR 11.5 for E5, E10 and E20.

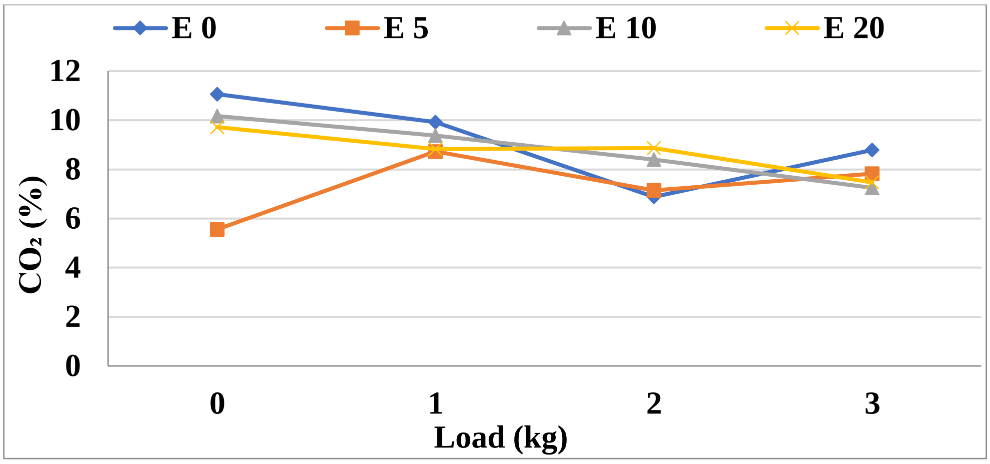

Figure 6 Load Vs CO_2 at CR 10

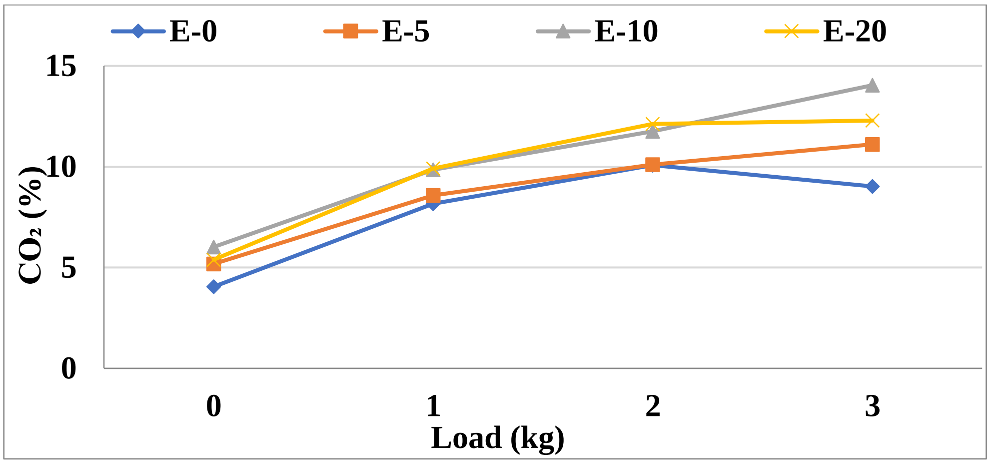

Figure 7 Load Vs CO_2 at CR 10.5

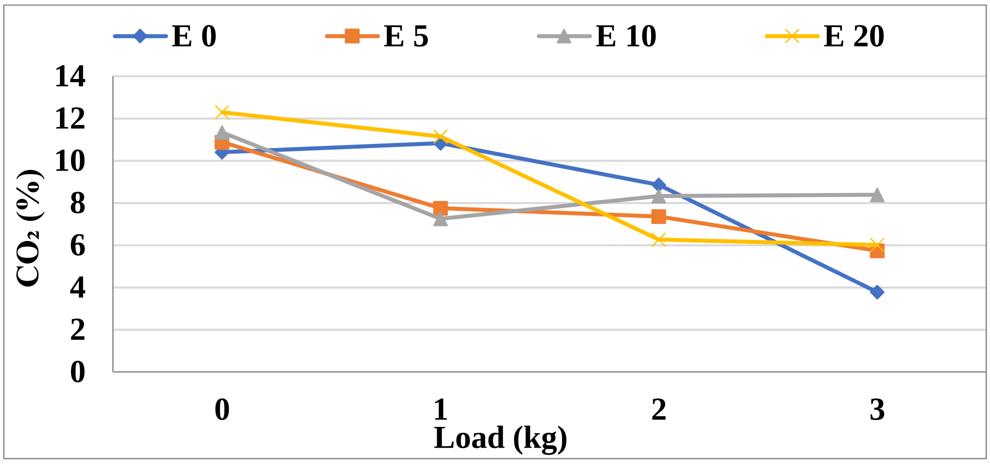

Figure 8 Load Vs CO_2 at CR 11

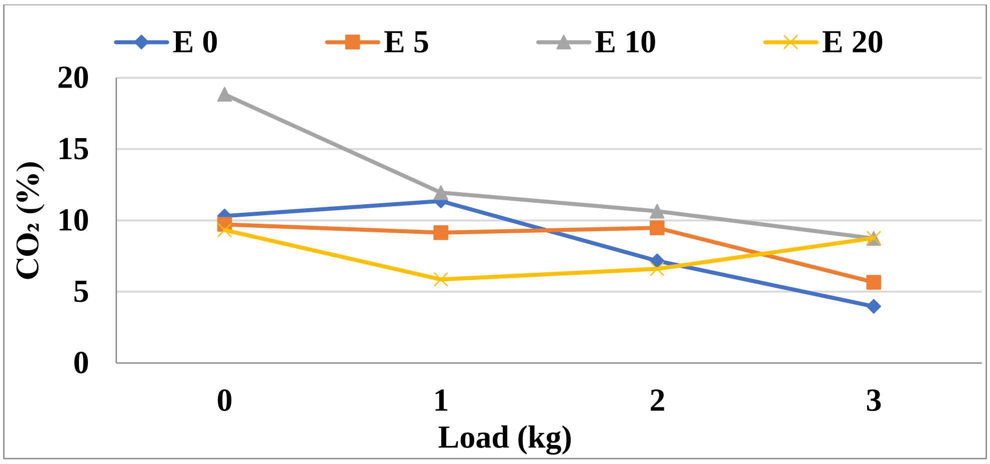

Figure 9 Load Vs CO_2 at CR 11.5

Load Vs HC

HC presence in the exhaust emissions shows the fuel was not burned completely and maybe because of blow-by losses inside the engine. The variations of HC emissions versus engine loads have been show in Figures 10, 11, 12 and 13. At CR 10, maximum HC emissions are 2230 ppm at 3 kg load for E20, and minimum HC emissions are 147 ppm at 0 kg load for E0. At CR 10.5, maximum HC emissions are 3314 ppm at 0 kg load for E20, and minimum HC emissions are 218 ppm at 3 kg load for E5. At CR 11, maxi-mum HC emissions are 2002 ppm at 3 kg load for E20, and minimum HC emissions are 191 ppm at 0 kg load for E0 and E5. At CR 11.5, maximum HC emissions are 2650 ppm at 3 kg load for E10, and minimum HC emissions are 176 ppm at 0 kg load for E0. It was found that as engine load increases the HC emissions increases because of incomplete combustion of fuel. Lack of oxygen, low temperature, and mixture heterogeneity are the main causes of incomplete combustion and HC production. By reducing HC emissions, blended fuel helps in complete combustion and accelerates wall quenching process.

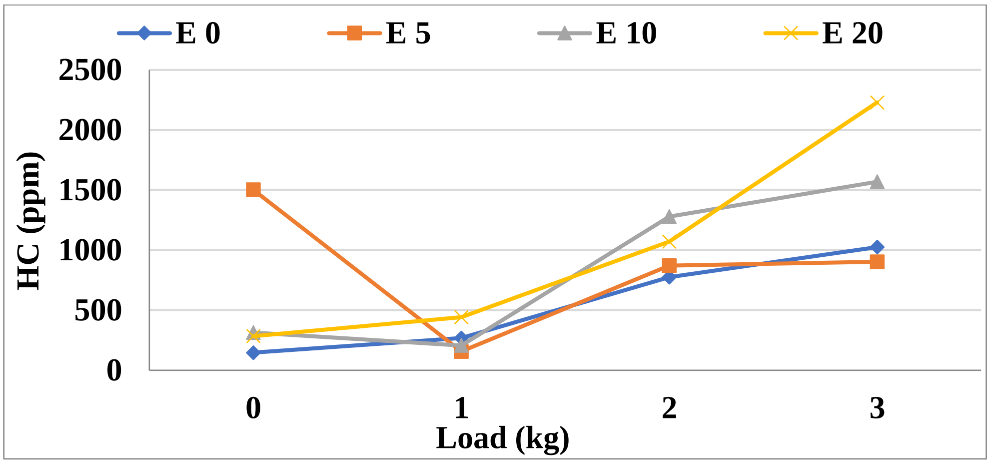

Figure 10 Load Vs HC at CR 10

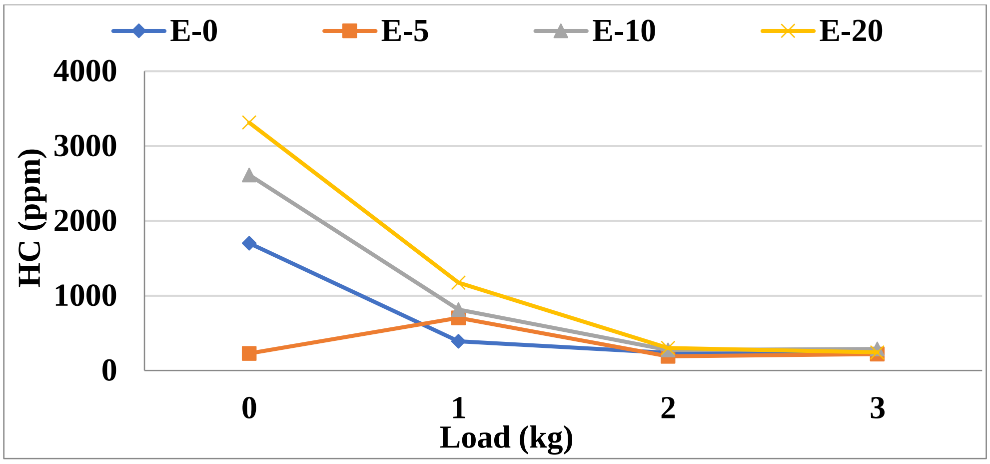

Figure 11 Load Vs HC at CR 10.5

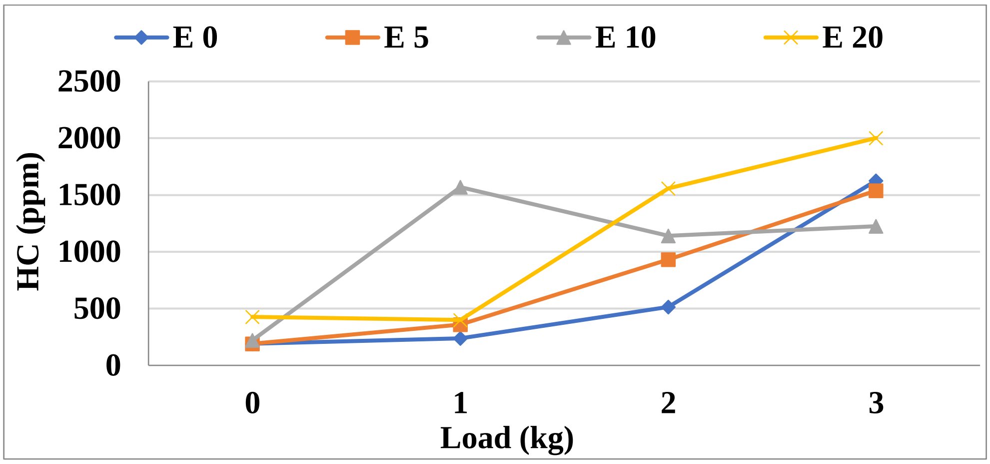

Figure 12 Load Vs HC at CR 11

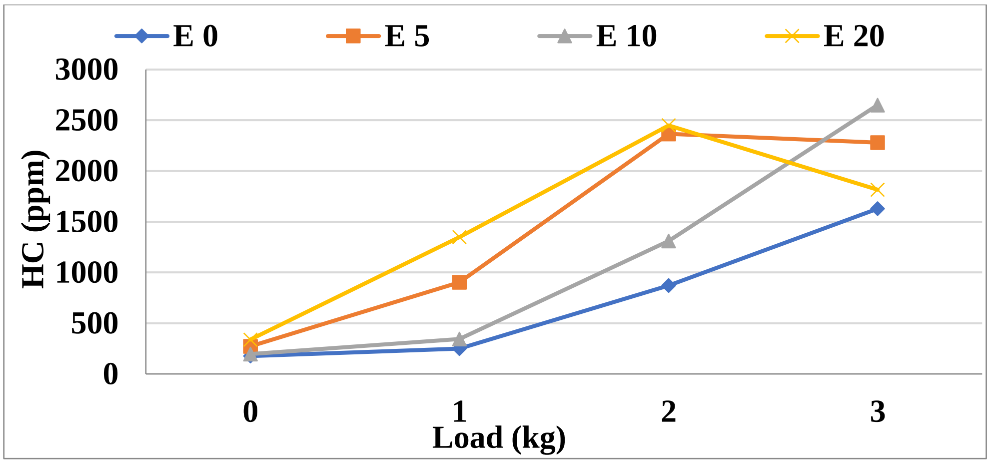

Figure 13 Load Vs HC at CR 11.5

Load Vs NOx

NOx emissions are usually produced from the reactions between oxygen and nitrogen the combustion of fuels, particularly at high temperatures. The variations of NOx emissions versus loads have been shown in Figures 14, 15, 16 and 17. At CR 10, maximum NOx emissions are 2726 ppm at 0 kg load for E0, and minimum NOx emissions are 227 ppm at 0 kg load for E5. At CR

10.5, maximum NOx emissions are 2954 ppm at 2 kg load for E0, and minimum NOx emissions are 136 ppm at 0 kg load for E20. At CR 11, maximum NOx emissions are 3628 ppm at 0 kg for E20 fuel, and minimum NOx emissions are 254 ppm at 3 kg load for E20. At CR 11.5, maximum NOx emissions are 3003 ppm at 0 kg for E0, and minimum NOx emissions are 264 ppm at 2 kg load for E20. As the compression ratio rises, the volume of the cylinder expands, compressing the fuel inside the cylinder. This can also be linked to an increase in fuel consumption as load rises, causing a rise in temperature during the combustion process and consequently an increase in NOx. Because quick flame propagation of hydrogen permits consistent combustion, delaying ignition time helps at a higher level in reducing NOx emissions without compromising engine performance.

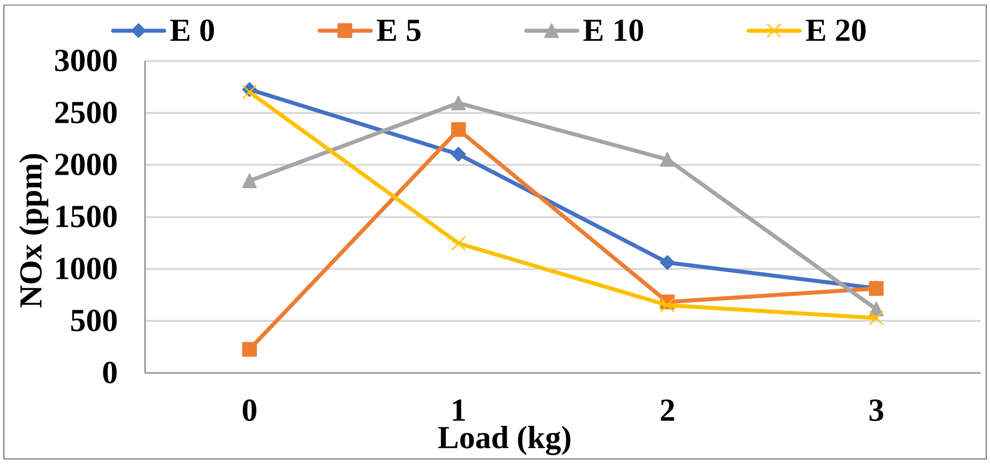

Figure 14 Load Vs NOx at CR 10

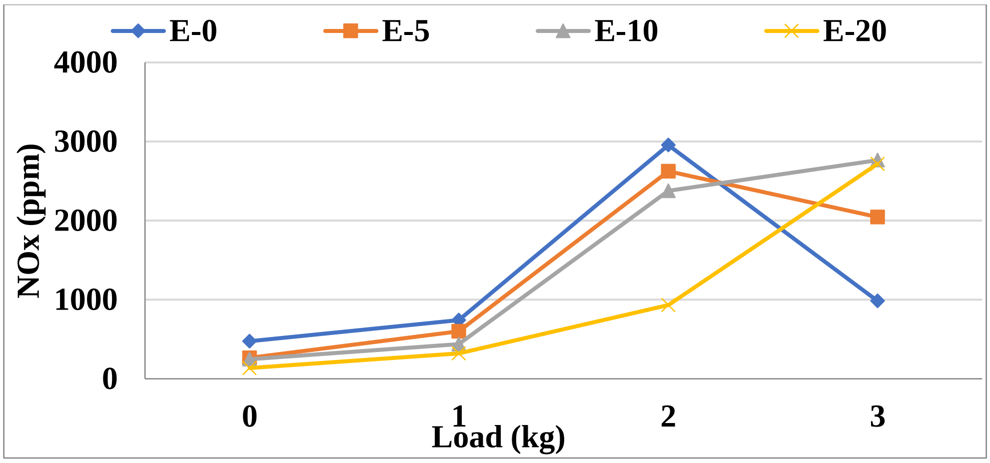

Figure 15 Load Vs NOx at CR 10.5

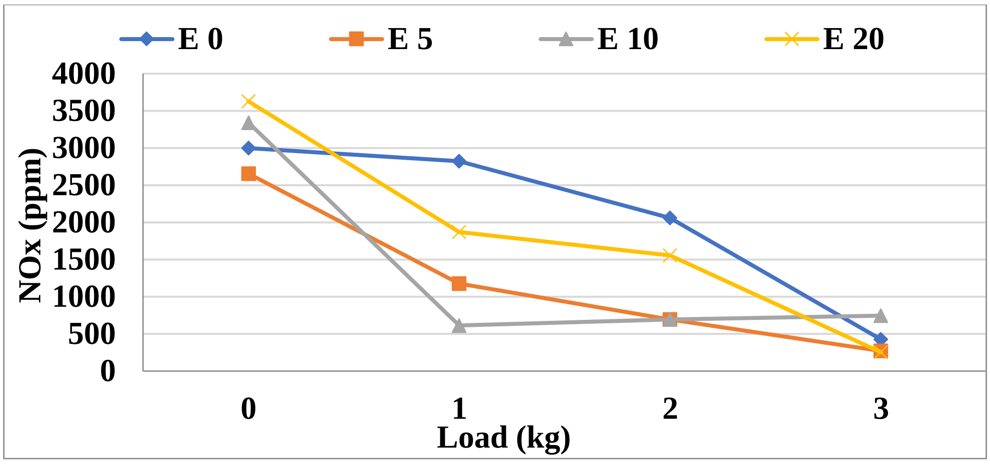

Figure 16 Load Vs NOx at CR 11

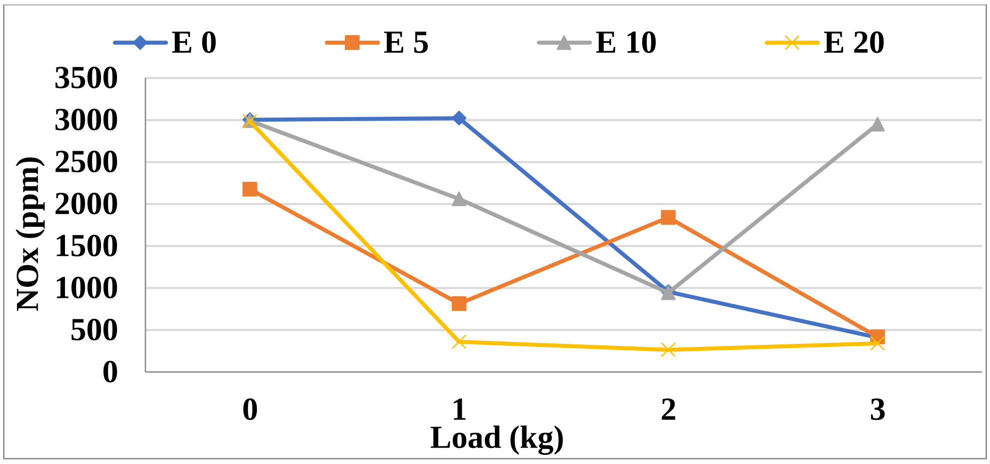

Figure 17 Load Vs NOx at CR 11.5

5. CONCLUSION

The following points can conclude from the work of combustion and emission analysis of E0, E5, E10 and E20 for compression ratios CRs (10:1, 10.5:1, 11:1 and 11.5:1).

1. CO emissions were found lower at 0 kg load for E5, E10 and E20 at CR 10, at 3 kg load at CR 10.5, at 2 kg load at CR 11, and at 0 kg load at CR 11.5, As compared to E0.
2. CO_2 emissions were found higher at 0 kg, 1 kg and 3 kg load for E0 at CR 10.5, and at 3 kg load for E0 at CR 11.5, as compared to E5, E10 and E20. On the other hand, CO_2 emissions were found lower at 0 kg, 1 kg, 3 kg load for E5, E10 and E20 at CR 10, and at 2 kg load at CR 11, as compared to E0.
3. HC emissions were found higher for E20 at 1 kg, 3 kg load at CR 10, at 0 kg, 1 kg, 2 kg load at CR 10.5, at 0 kg, 2 kg, 3 kg load at CR 11, and at 0 kg, 1 kg and 2 kg load at CR 11.5, as compared to E10, E5 and E0.
4. NOx emissions were found lower at 0 kg load for E5, E10 and E20 at CR 10, at 0 kg, 1 kg and 2 kg load at CR 10.5, at 1 kg, 2 kg load at CR 11, and at 1 kg load at CR 11.5, as compared to pure gasoline E0.
5. Ethanol has higher octane no. than gasoline, which helps to reduce the engine's knocking tendency.

6. The SI engine can run satisfactorily without modification using gasoline-ethanol mixtures as a fuel (up to E20, and a load of up to 3 kg).

   As we increase the ethanol percentage in gasoline the harmful emissions decreases because ethanol as bio-fuel has low carbon emissions as compared to pure gasoline. Hence, we can conclude that using gasoline-ethanol blend can help in controlling the air pollution and we can preserve fossil fuels for the future.

Declarations

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