The Effect of Gasoline –Ethanol Blends and Compression Ratio on SI Engine Performance and Exhaust Emissions

K. Manikandan* Menelik walle**

*Assistant Professor   ** Professor and Head

Department of Motor vehicle Engineering, Defence Engineering College, Ethiopia- 1041

ABSTRACT:

In this study the effects of gasoline-ethanol blends(E10,E20 and E30) and two different compression ratio(6:1 and 8:1) on single cylinder four stroke air cooled variable compression ratio SI engine have been experimentally investigated. The experimental results showed that increase of ethanol blending leads to slightly increase the Engine power output, torque and significantly increase the Specific fuel consumption (SFC). CO and HC emission decreases dramatically, CO_2 and No_x emissions decrease significantly. When the engine was operating with E30 fuel at higher compression ratio (8:1), the CO and Specific fuel consumption (SFC) reduces drastically with compared to lower compression ratio (6:1). Engine performance and CO_2, NO_X, HC emissions for E30 fuel with higher compression ratio (8:1) were increased significantly compared to lower compression ratio (6:1).But Exhaust emissions of E30 fuel with compression ratio 8:1 is very lower than E0 fuel with compression ratio 6:1. It was also observed that the increase of ethanol blending allows the engine to operate at higher compression ratio without knock occurrence.

Keywords: Spark ignition engine; Ethanol; Engine Performance; pollutant Emission; High Compression ratio

1. Introduction

The Recent researches focusing on lowering the concentration of toxic components in combustion product and decreasing fuel consumption by using renewable , sustainable and non polluting fuels[1].The stringent pollution regulations and increasing energy demand as a result of technological development in the world promote research on alternative fuels[2].The high heat of vaporization of ethanol and their high octane rating have made them preferred fuel for use in high compression ratio, high output SI engines. High octane values which can permit significant increase of compression ratio and high heats of evaporation which can provide fuel-air charge cooling and density increase and thus higher mass throughout [3].The alcohol-gasoline blended fuels can effectively lower the pollutant emission without major modifications to engine design [4,5].The usage of alcohols as a fuel for SI engines, have some other advantages over gasoline. Such as the reduction of CO and HC emissions [6].Ethanol have high heat of vaporization, it reduces the peak temperature inside the cylinder and hence reduces the NOx emissions[7].The engine performance and pollutant emission of an SI engine using gasoline–ethanol blends(E0,E5,E10,E20 and E30)were investigated experimentally by wu, chen and Lin [8].The results indicated that torque output and fuel consumption slightly increase; CO and HC emissions decreases dramatically, when using gasoline ethanol blended fuel. In another study by Yusesu, Topgul, cinar and okur [9] gasoline ethanol blended fuels (E0, E5, E10, E20 and E30) were tested in a conventional SI engine under various air-fuel equivalence ratios for its performance and emissions. The results of the showed that torque output increased slightly at small throttle opening. When gasoline ethanol blended fuel was used. it was also shows that CO,CO_2 and HC emissions were reduced with the increase of ethanol content in the blended fuel. [10] investigated the effects gasoline-ethanol blends (E0,E10,E20,E40 and E60) on engine performance and exhaust emissions in different compression ratios(8:1 to 13:1) According to the results of experiments it was found that as the compression ratio increased engine torque and emissions also increased. From the literature survey Gasoline ethanol blended fuel can be used effectively in SI engine with little or without any modifications. Ethanol has higher octane number, higher evaporation heat and low evaporation pressure compared with gasioline.The conventional carburetor version SI engine the ethanol blending with gasoline is limited to 30%. Because the carburetor is not capable to evaporate all the fuel supplied to the engine, and part its enter the chambers without vaporization. This causes the reduction in the brake power and thermal efficiency as the ethanol % increased beyond 30%. If the amount of ethanol increased in the blended fuel the heating value decreases. But another hand increase of ethanol amount in the blended fuel enables to decrease of air fuel ratio. So we can take much more fuel during the intake process. Ignition timing, excess air ratio, latent heat of vaporization, compression ratio and flame speed have also influence the engine performance. In this study, the effects of compression ratio and gasoline-ethanol blends (E10, E20 and E30) on engine performance and pollutants emissions were investigated in a single cylinder, four stroke, and variable compression ratio SI engine

2. Experimental Studies

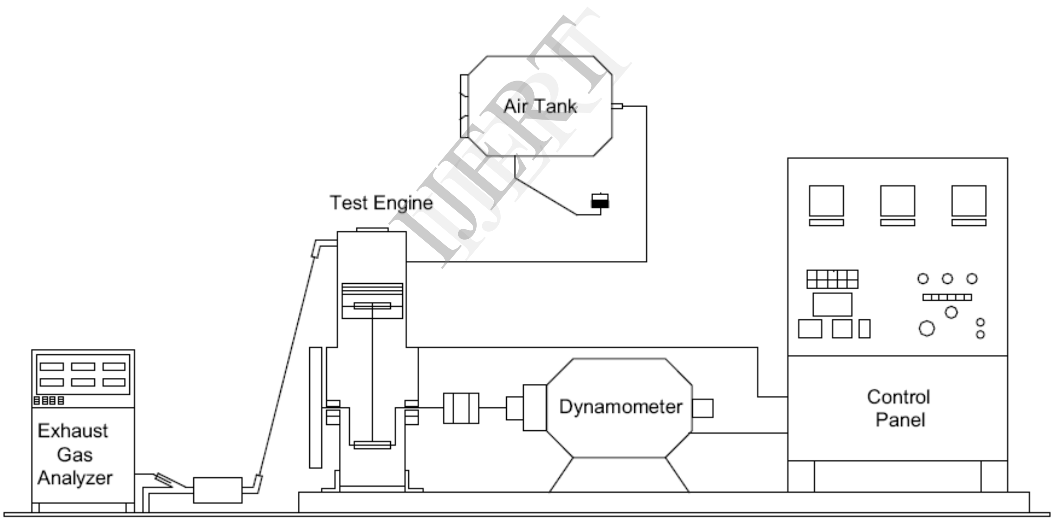


Fig. 1. Schematic view of the engine test bed.

The experimental set up is shown in Fig.1. Consists of a SI Engine test bed with dc dynamometer and exhaust gas analyzer. In the test, a single cylinder four stroke air cooled variable compression ratio SI engine was used. The compression ratio is varied by the counter piston is actuated by a screw rod mechanism. The overhead cylinder is water cooled externally and has an encounter piston above the original pistons in the main engine. Table.1. shows the specification of the test engine. The properties of ethanol and gasoline fuel are shown in table.3. QRO 401(Qrotech Company Ltd. Korea) exhaust gas analyzer was used for measure the exhaust gas emissions. The specifications of exhaust gas analyzer are given in table.2. Test engine incylider pressure was measured by the pressure measurement setup. The test was conducted for three different gasoline and ethanol blends namely E10, E20 and E30 fuel with compression ratio 6:1 in the first stage of experiment. In the second stage E30 fuel with compression ratios of 6:1 and 8:1 were investigated. All the data for engine power, specific fuel consumption, CO, HC, CO_2 and NOx emissions were collected .At all the tests, all values were recorded after allowing sufficient time for the engine to stabilize.

Nomenclature

SFC	Specific fuel consumption, g/kWh
CR	Compression ratio
E0	Unleaded gasoline
E10	10% ethanol+90% unleaded gasoline
E20	20% ethanol+80% unleaded gasoline
E30	30% ethanol+70% unleaded gasoline
HC	Hydrocarbon, ppm
NOx	Nitrogen oxides, ppm
CO	Carbon monoxide, vol%
CO2	Carbon dioxide, vol%
SI	Spark ignition
WOT	Wide open throttle
λ	Excess air factor

3. Results and discussions

The experiments were conducted in two stages. At first stage the engine was tested with compression ratio 6:1 with the various gasoline-ethanol blends (E10, E20 and E30) on engine performance and exhaust emissions. In second stage the compression ratio was raised from 6:1 to 8:1 and the test was performed.

Table.1
Specifications of the test engine

Make	: Tech-ED Equipment Company
Engine type	: Four-stroke, single cylinder
Bore	: 70 mm
Stroke	: 66.7mm
Compression ratio	: 2.5:1 to 8:1
Rated speed	: 3000 rpm
Cooling system	: Air and water cooled
Fuel system	: Carburetor version

Table.2
Specification of the Exhaust gas Analyzer

	Measurements Range	Accuracy
CO(vol%)	0 - 9.99	0.01
CO2(vol%)	0 - 20	0.1
HC(ppm)	0 - 9999	1
NOx (ppm)	0 - 4000	1
O2 (vol %)	0 - 25	0.01
AFR	0 – 99	0.1
λ	0 – 2	0.001

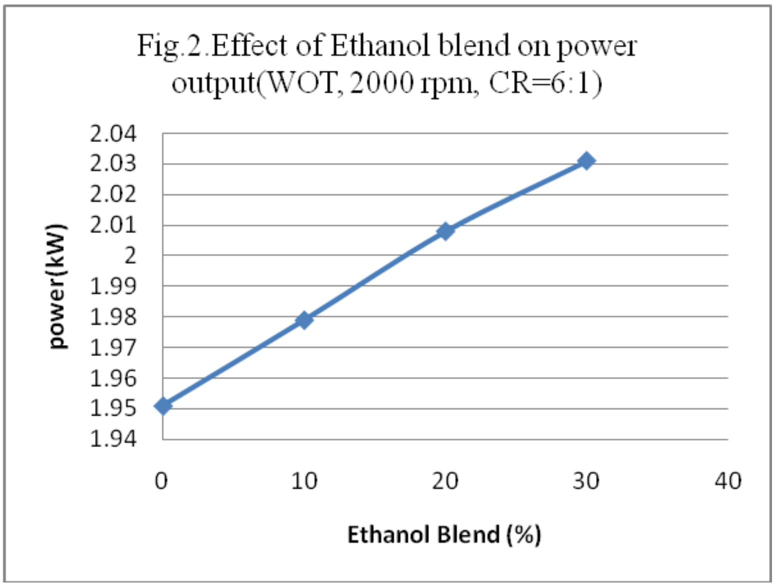
3.1. Power and specific fuel consumption:

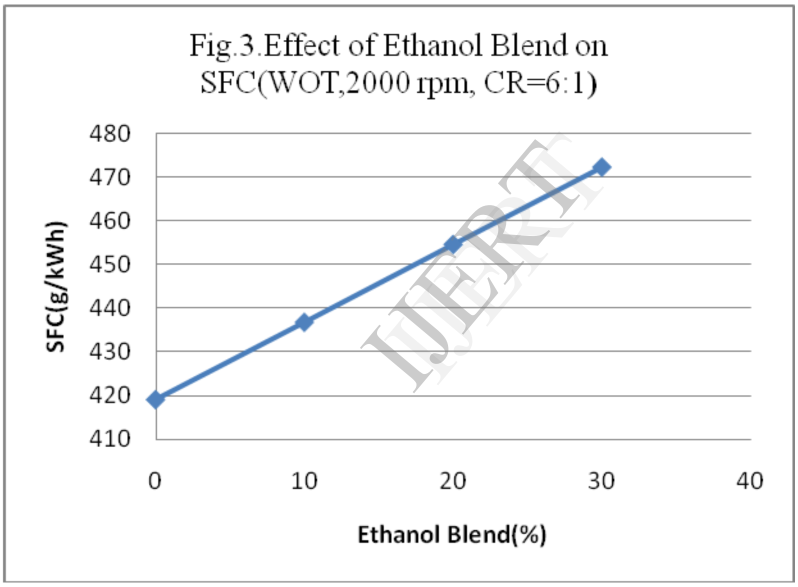
Fig.2 & Fig.3 shows the effect of various blends on power and SFC respectively. As the Ethanol Content in the blended fuel increases power also increases slightly when compared with E0 fuel, the power increases of 1.2%, 2.5% and 4% are obtained with E10, E20 and E30 fuels respectively. This is due to several reasons ethanol as an oxygenated fuel, so complete combustion is possible, the heat of evaporation of ethanol is higher than that of gasoline. High heat of evaporation can provide fuel-air change to cool and density to increase, so volumetric efficiency is increased ultimately power increases slightly [3]. The SFC increases with increase of ethanol content in the blend. The reason is the heating value of ethanol is lower than that of gasoline. The increase of 4%, 8.5%, 13.2% in the SFC Observed when running with E10, E20 and E30 respectively.

Table.3

The properties of gasoline and ethanol

Fuel property	Gasoline	Ethanol
Formula	C8H18	C2H5OH
Molar C/H ratio	0.445	0.333
Molecular weight (kg/kmol)	114.18	46.07
Latent heating value (MJ/kg)	44	26.9
Stoichiometric air/fuel ratio	14.6	9
Auto-ignition temperature (°C)	257	425
Heat of vaporization (kJ/kg)	305	840
Research octane number	88–100	108.6
Motor octane number	80–90	89.7
Freezing point (°C)	40	114
Boiling point (°C)	27–225	78
Density (kg/m3)	765	785





3.2. The effects of various gasoline-ethanol blends on exhaust emissions

Fig.4. showed the effect of various blends on CO emission. Ethanol containing oxygen is mixed with gasoline, so the combustion of the engine becomes better ultimately it reduces the CO emissions [10]. Fig.2. shows the values of CO emissions are about 3.8% 3.36%, 2.9% and 2.47% forE0, E10, E20 and E30 fuel respectively.

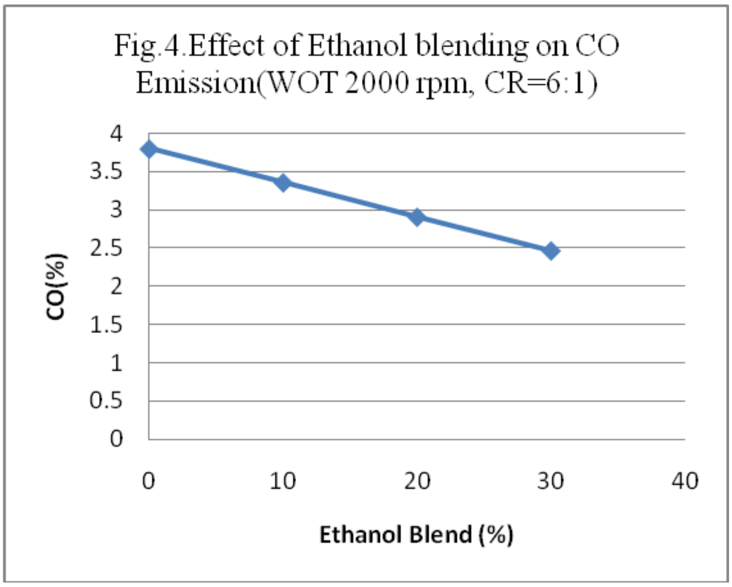
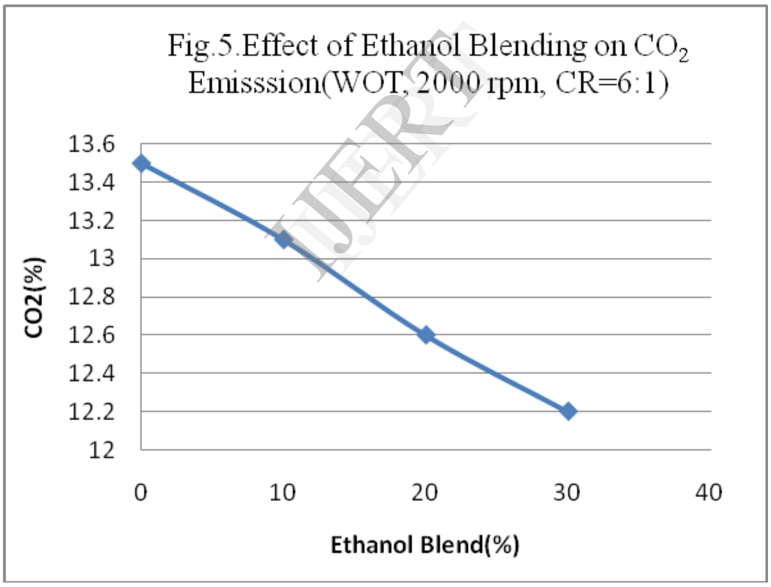
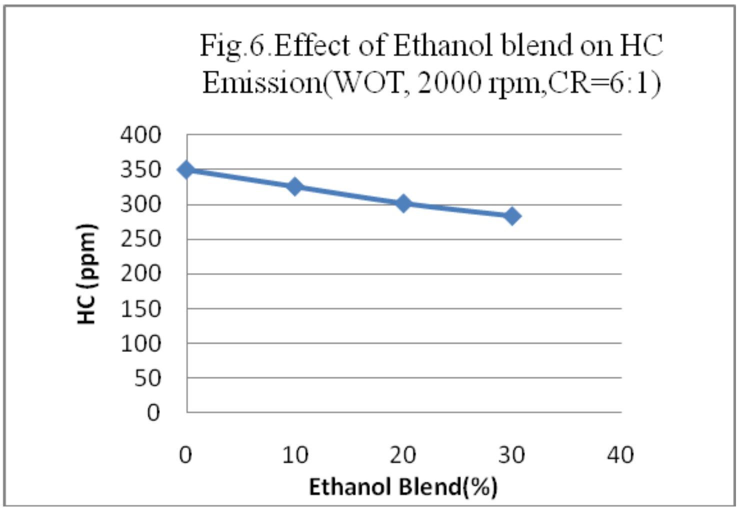


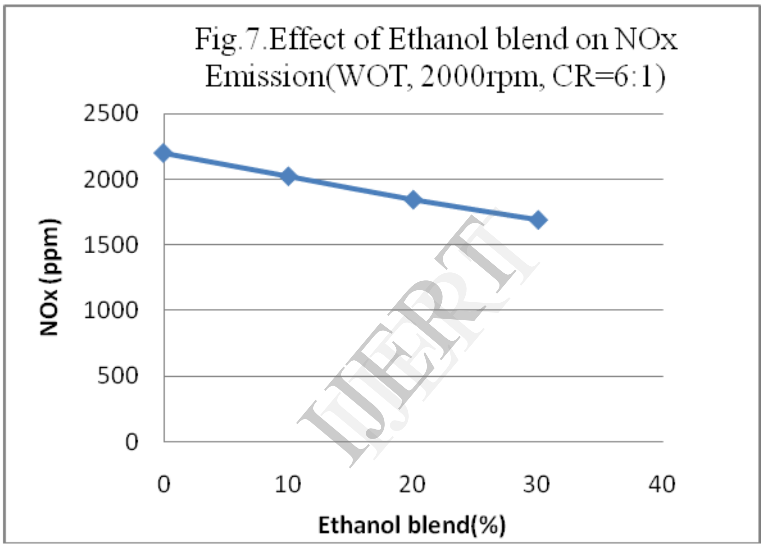
Fig.5. shows the effect of various blends on CO_2 emission. The CO_2 emission decreases with when ethanol blend increases. Because the ethanol contains lower carbon atoms than gasoline it gives net lower CO_2 [8]. The values of CO_2 are about 13.5%, 13.1%.12.6% and 12.2% for E0, E10, E20 and E30 fuel respectively.



The effect of various blends on HC and NOx emission given in Fig.6&Fig.7 respectively. Increase of ethanol content in the blend fuel upto 30%, the CO and HC emissions decrease Because ethanol contains an oxygen atom, It can be treated as a partially oxygzied hydrocarbon. The values of HC 350 ppm, 326ppm, 302ppm and 284ppm for E0, E10, E20 and E30 fuel respectively .As the ethanol content in the blend increases NOx decreases it shown in Fig.7. The values of NOx 2200 ppm, 2024ppm, 1847ppm, and 1694ppm for E0, E10, E20 and E30 fuel respectively. Ethanol has high heat of vaporization compared to gasoline so the mixture temperature at the end of intake stroke decreases and ultimately causes temperature to decrease, so the engine NOx emissions decrease[11]

The first stage experiment results shows that upto30% of ethanol blend in the gasoline reduces the CO ,CO_2,NOx and HC emissions and the power output,SFC increases slightly.



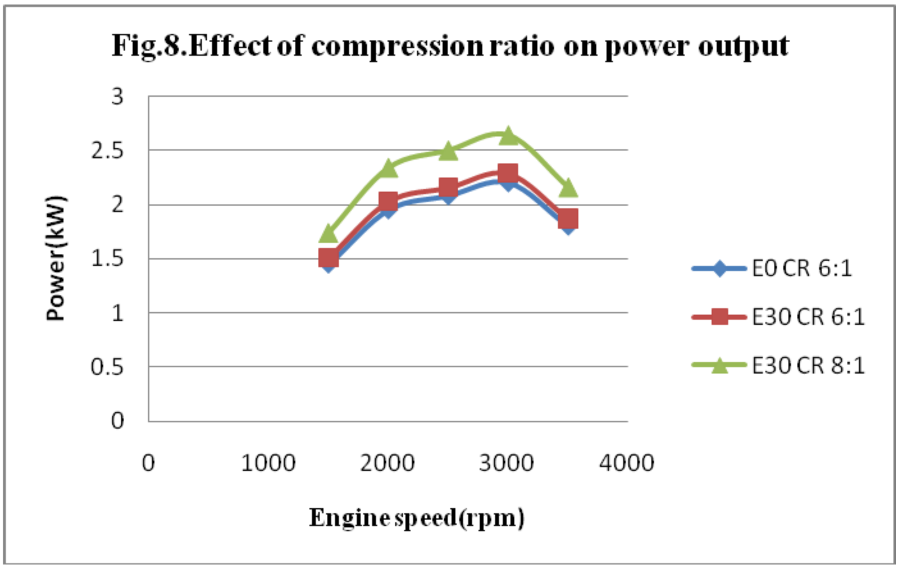


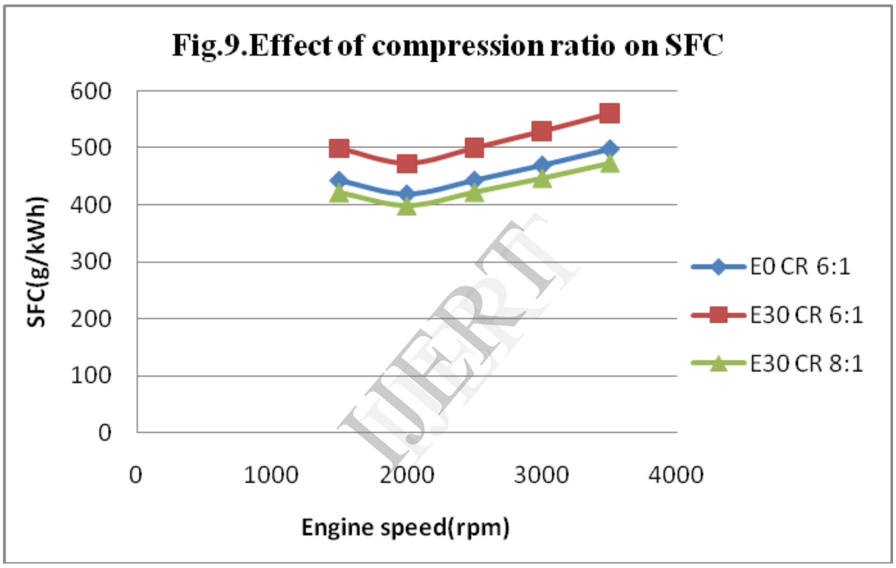
In the second stage, the compression ratio was raised from 6:1 to 8:1 and the engine was tested with E30 fuel and baseline fuel (i.e. E0) for comparison. This test was conducted at full load in the speed range from 1500 rpm to 3500 rpm and speed interval of 500 rpm, Excess air factor (λ) maintained one. The engine runs smoothly when operate with E30 blend fuel compared with E0.

3.3. The effect of E0 and E30 fuels on power and SFC at various compression ratio

Fig.8 shows the effect of E0 and E30 fuels on power at various compression ratios. The power obtained with E30 fuel is about 4% higher than that with E0 at the same compression ratio (6:1). The engine could run with E30 fuel without knock at the compression ratio of (8:1) and a power increase of 15% was obtained when compared to running with E0 at the compression ratio of 6:1.

The effect of E0 and E30 fuels on SFC at the various compression ratios given in Fig.9. The minimum SFC of E0 fuel is 420g/kWh at the compression ratio of 6:1 and 2000 rpm. When the engine runs with the E30 fuel with the same compression ratio (6:1) SFC increases about 13.2%. Due to lower heating values of ethanol. When the engine runs with E30 fuel at the compression ratio of 8:1 the SFC decreases by about 5% compared with E0 fuel at the compression ratio 6:1.





3.4. The Effect of E0 and E30 fuels on exhaust emission at various compression ratios

The effect of E0 and E30 fuels with two different compression ratios on CO emission is shown in Fig.10. For the same compression ratio (6:1), the CO emission obtained with E30 is about 35% lower than E0 fuel.CO emission depends on air fuel ratio. When ethanol content increases, CO emission is reduced due to oxygen enrichment resulting from the ethanol. When the engine is run with E30 fuel at the compression ratio of 8:1. 8% lower CO emission is shown in Fig.10. When compared to the running with E30 fuel at the compression ratio of 6:1.

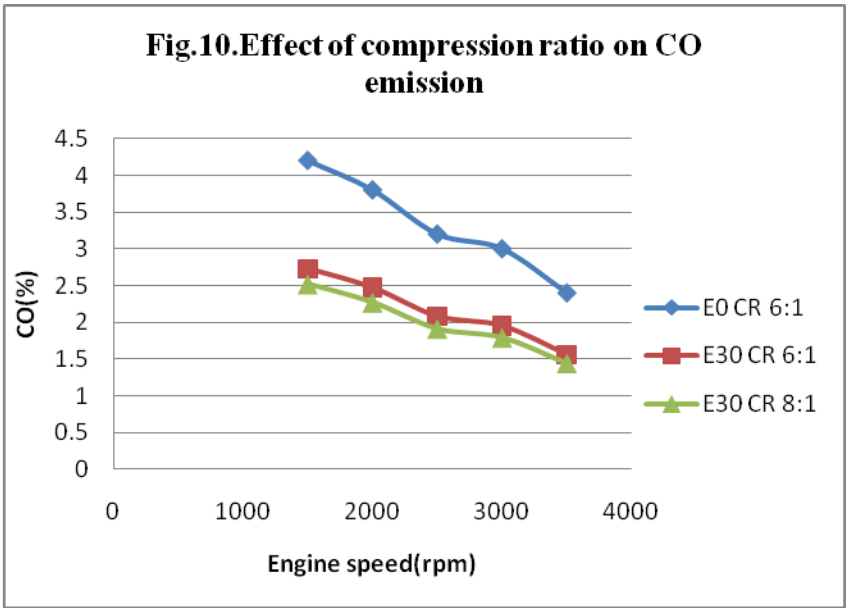


Fig.11shows the effect of E0and E30 fuels with two different compression ratio on CO_2 emission. For E30 fuel CO_2 emission obtained at the compression ratio of 8:1 is about 8% lower than that with E0 fuel at the compression ratio of 6:1. Where the Fig.10 and Fig.11 explained together, it is seen that CO_2 increases as CO decreases with increasing engine speed.CO and CO_2 have complementary correlation that is with increasing CO emission the amount of CO_2 decreases. CO_2 emission depends on air fuel ratio and CO emission concentration [8].

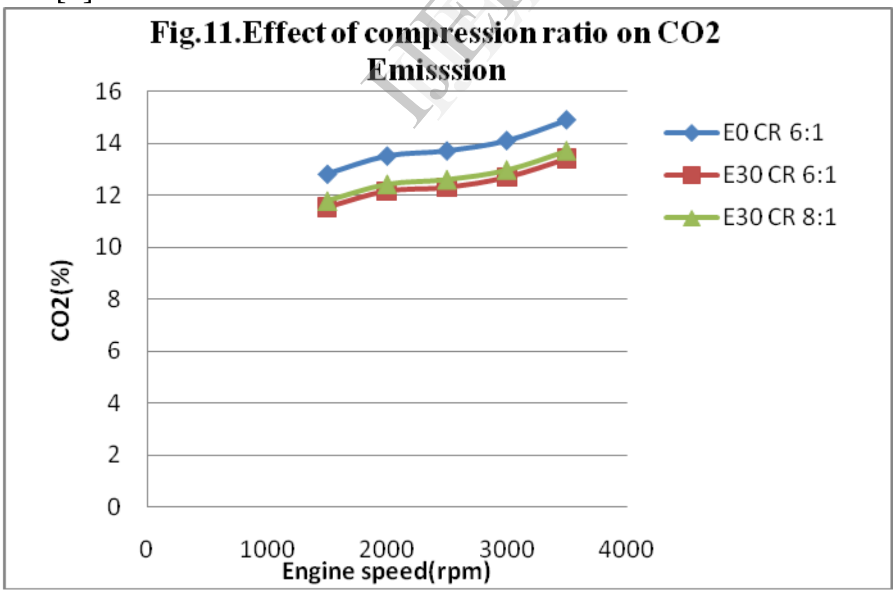
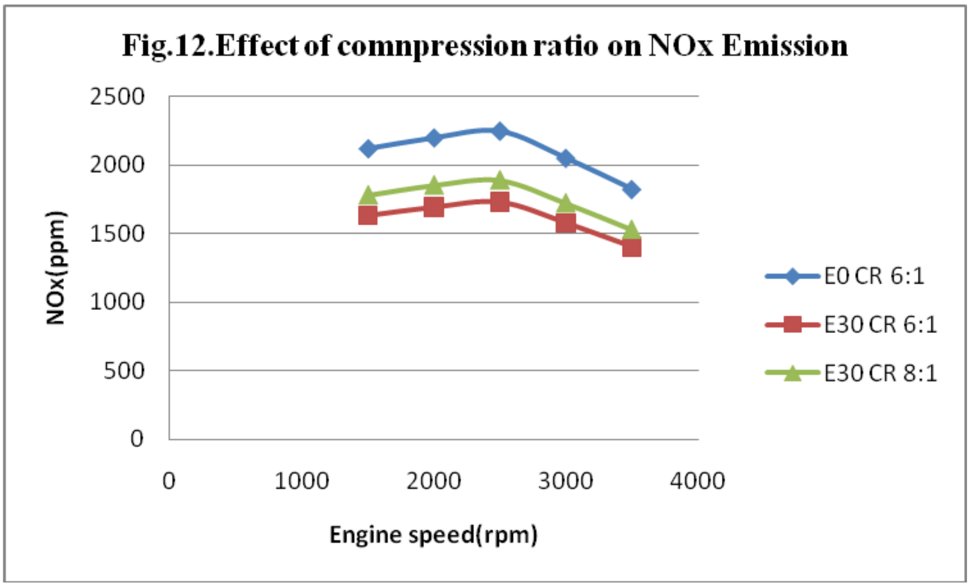
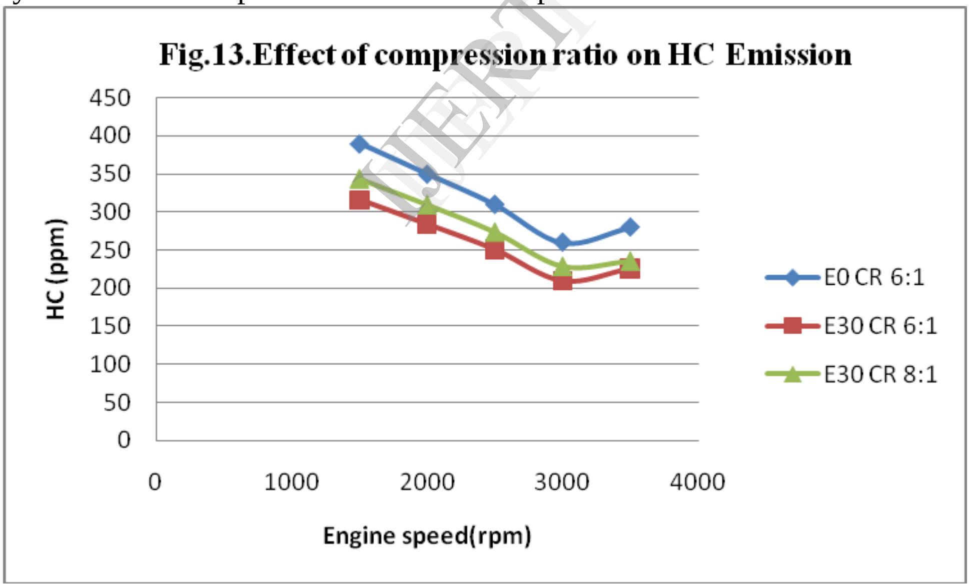


Fig.12 shows the effect of E0 and E30 fuels with two different compression ratio on NOx emission obtained with E30 fuel at the compression ratio 6:1 is about 23% lower than that with E0 fuel at the same compression ratio (6;1). For E30 fuel NOx emission increases by about 9% with increasing compression ratio from 6:1 to 8:1. The compression ratio increases the combustion temperature also increases ultimately it increases the NOx. Engine running with E30 fuel at compression ratio 8:1, NOx decreases by 16% compared to E0 fuel at a compression ratio of 6:1.



The effect of E0 and E30 fuels with two different compression ratio on HC emission is given in Fig.13. For same compression ratio(6:1) HC emission obtained with E30 fuel is about 19%lower than that with E0 fuel.E30 fuel HC emission increases by about 9% with the increase in compression ratio from 6:1 to 8:1.As the compression ratio increases, the combustion chamber surface/volume ratio also increases and this in turn, increases the HC emission.[12].When engine running with E30 fuel at compression ratio8:1, HC emission decreases by about 12% compared to E0 fuel at compression ratio 6:1.



4. Conclusion

In this study the effect of gasoline-ethanol blends (E0, E10 and E30) and two different compression ratio(6:1 and 8:1) on engine performance and Exhaust emissions were investigated in a single cylinder air cooled four stroke SI engine. From the experimental results, it was determined that.

- Upto30% of ethanol blending with gasoline reduces the CO, CO_2, HC and NOx emissions. Power output increases 4% and SFC increases about13% for E30 fuel at compression ratio (6:1).

- At higher compression ratio(8:1) the power output increases 15% and SFC decreases5% for E30 fuel compared to when the engine operate at lower compression ratio(6:1) with E0 fuel
- E30 fuel operate with higher compression ratio(8:1), the CO_2,NOx and HC emission increases.CO emission reduces compared to E30 fuel operate at lower compression ratio(6:1).but all the pollutant emissions for E30 fuel with compression ratio(8:1) are very lower than E0 fuel operate at lower compression ratio(6:1)
- Blending of ethanol with gasoline fuel enables the engine to run without any knock at high compression ratio at full load and all speeds.

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