Effects of Ethanol-Gasoline blends on Performance and Emissions of Gasoline Engines

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Abstract – *This paper reviewed the experimental works on performance and emissions of SI engines fuelled with ethanol-gasoline blends. The effect of compression ratio CR on performance and emission of engine fuelled with ethanol-gasoline blends has also been discussed. It was reported that ethanol-gasoline blends allowed increased compression ratios(CR) without knocking. The results showed that ethanol addition to gasoline increase the engine torque, power and fuel consumption and reduce carbon monoxide (CO), nitrogen oxides (NO_x) and hydrocarbon (HC) emissions. The blending of ethanol with gasoline up to50% gives better performance and reduced emissions as compared to SI engines, at high compression ratios.*

***Key Words*: Ethanol, Ethanol Blends, NO_x , CO, HC, Spark Ignition engine, Internal Combustion engine.**

1.INTRODUCTION

Developing renewable alternative fuel for IC engine has become an important part of energy policy of governments worldwide, because of scarcity of petroleum and global warming. Alternative fuels such as vegetable oils, hydrogen, alcohols, natural gas and biogas are potential alternative fuels for IC engine.

Alcohols have been used as fuel for IC engines since 19th century. Among the various alcohols, ethanol is known as the most suited renewable, bio-based and eco-friendly fuel for spark-ignition (SI) engines. The most attractive properties of ethanol as an SI engine fuel are that it can be produced from renewable energy sources such as sugarcane, cassava, corn, barley and many types of waste biomass materials. In addition, ethanol has higher evaporation heat, octane number and flammability temperature therefore it has positive influence on engine performance and reduces exhaust emissions.

1.1 Abbreviations

BSFC – brake specific fuel consumption

CO – carbon monoxide

CO_2 – carbon dioxide

CR – compression ratio

E0 – gasoline without ethanol

E40 – 40% ethanol + 60% gasoline (vol%)

E50 – 50% ethanol + 50% gasoline (vol%)

E60 – 60% ethanol + 40% gasoline (vol%)

E85 – 85% ethanol + 15% gasoline (vol%)

E100 – 100% ethanol + 0% gasoline (vol%)

HC – hydrocarbons

NO_x – nitrogen oxides

rpm – engine speed

SFC – specific fuel consumption

SI – spark ignition

IC – internal combustion

1.2 Review of Experimental Works

Koç, et al.[1] were investigated experimentally, performance of a single cylinder four-stroke spark-ignition engine fueled with ethanol-gasoline blends. The tests were conducted at eight different engine speeds ranging from 1500 to 5000 rpm at two different compression ratios (10:1 and 11:1). Three different fuels tested are E0, E50 and E85.

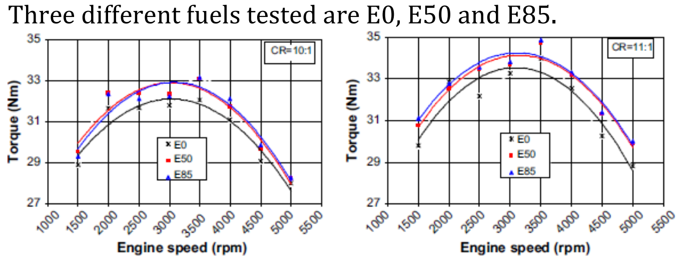


Fig.1. The effect of ethanol-gasoline blends on engine torque at different CR

It was noticed that with blended fuels (E50 and E85) torque was higher than that of base gasoline. The average increment was recorded in engine torque compared with E0 was about 2% with E50 and E85 at CRof 10:1. The average increment was recorded in engine torque compared with E0 was about 2.3% and 2.8% with E50 and E85 at CR of 11:1 respectively. Torque is increased when using ethanol-gasoline blends due to several reasons. Ethanol has low heating value, higher density, higher latent heat of evaporation, more oxygen as compared to base gasoline.

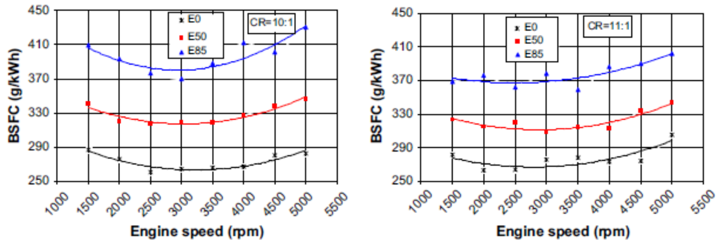


Fig.2. The effect of ethanol-gasoline blends on engine BSFC at different CR

Ethanol have heating value is about 35% less than the values of gasoline. The BSFC was more for ethanol blended fuel because to produce the same power at the same operating conditions more quantity of fuel was required.It was observed that ethanol addition results 20.3% and 45.6% average increments in BSFC with E50 and E85 respectively at CR 10:1 and at CR11:1, BSFC increased with E50 and E85 fuel blends by 16.1% and 36.4% respectively as compared to E0.

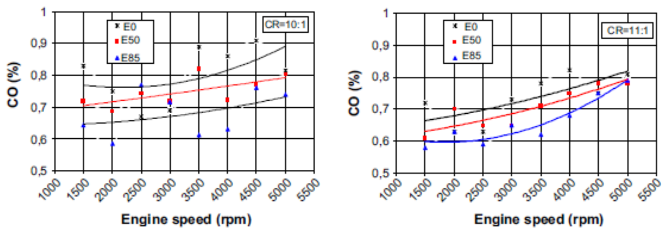


Fig.3. The effect of ethanol-gasoline blends on CO emissions at different CR

CO produced because of incomplete combustion due to insufficient amount of air in the air-fuel mixture or insufficient time in the cycle for completion of combustion. It was observed that CO emissions decreased with the addition of ethanol fuel in gasoline. CO emissions decreased at lower CR was lower than that of higher CR.

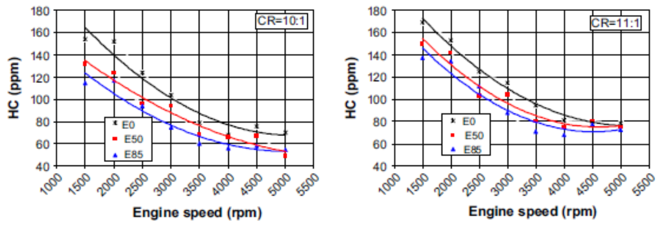


Fig.4. The effect of ethanol-gasoline blends on HC emissions at different CR

Reduction in HC emissions was observed between 1500 and 5000 rpm at CR 10:1 and 11:1. Maximum HC emission was observed with E85 fuel about 24% less than that of maximum HC emission with gasoline only.

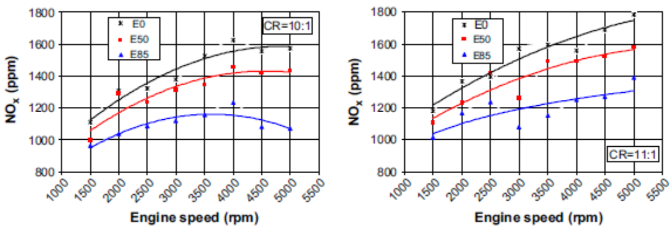


Fig.5. The effect of ethanol-gasoline blends on NO_x emissions at different CR

Reduction in NO_x emissions was obtained with ethanol addition due to the high latent heat of vaporization of ethanol. NO_x emissions at CR of 11:1 were slightly more than that at 10:1. It was also observed that ethanol-gasoline blends allow increasing CR without knock occurrence.

G. Najafi[2] performed experiments on four-cylinder SI engine running ongasoline and blended with ethanol-gasoline blends (E5, E10, E15 and E20).

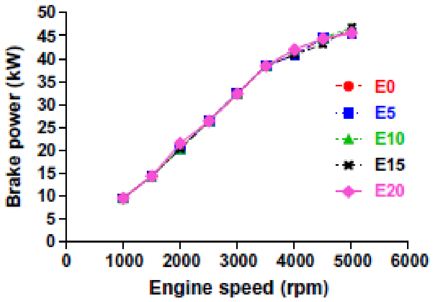


Fig.6. Experimental results of brake power at different fuel blends and engine speeds (rpm)

Brake power slightly increased for all engine speeds for blended fuel. The heat of evaporation of ethanol is higher than that of gasoline, this provides fuel-air charge cooling and increases the density of the charge, and thus higher power was obtained.

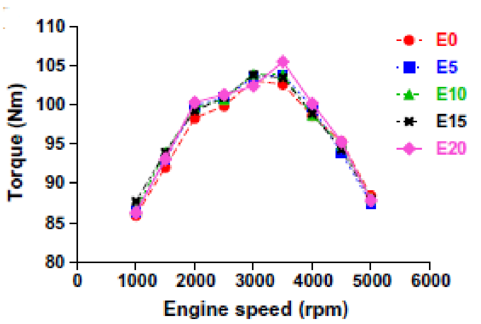


Fig.7. Experimental results of torque at different fuel blends and engine speeds (rpm)

Addition of ethanol increases the torque of the engine. Added ethanol produces lean mixtures that increase the relative air-fuel ratio to a higher value and makes the combustion more efficient.

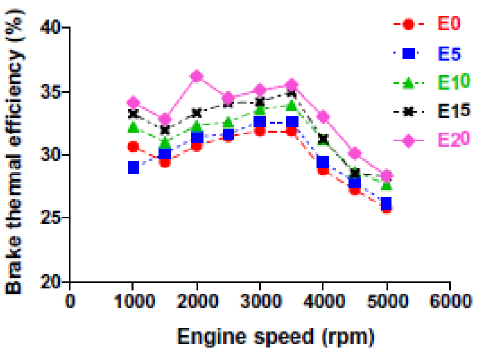


Fig.8. Experimental results of brake thermal efficiency at different fuel blends and engine speeds (rpm)

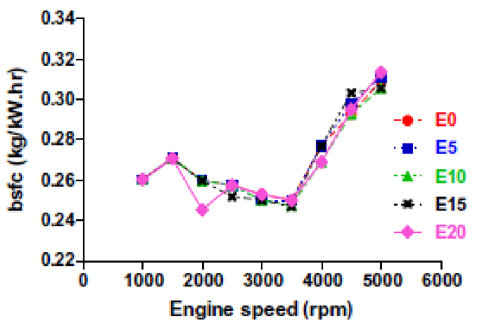


Fig.9. Experimental results of BSFC at different fuel blends and engine speeds (rpm)

The BSFC decreases on addition of ethanol content in gasoline. The lowest BSFC value observed at 3500 rpm.

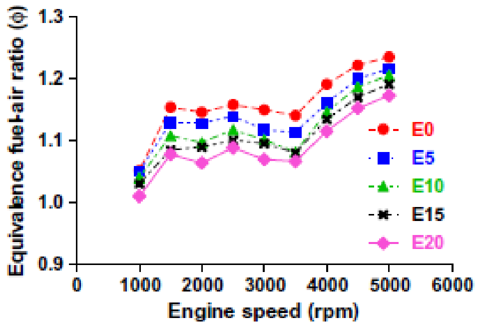


Fig.10. Experimental results of equivalence air-fuel ratio at different fuel blends and engine speeds (rpm)

Equivalence fuel-air ratio is the important parameter that affects engine performance parameters. It was recorded that equivalence fuel-air ratio decreased as the percentage of ethanol in the blended fuel increased.

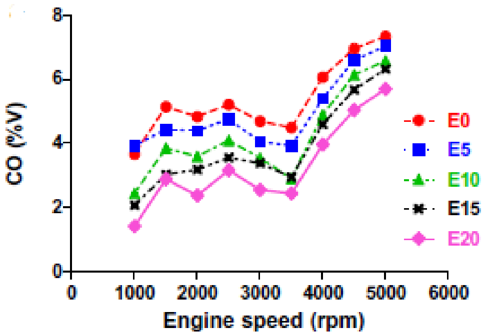


Fig.11.Experimental results of CO at different fuel blends and engine speeds (rpm)

Ethanol (C_2H_2OH) has less carbon than gasoline (C_8H_{18}). It is observed that when ethanol percentage increased, the CO emission decreased. CO concentrations at 3000 rpm using E5, E10, E15 and E20 was decreased by 13.7%, 24.31%, 27.93% and 45.42% respectively in comparison to gasoline.

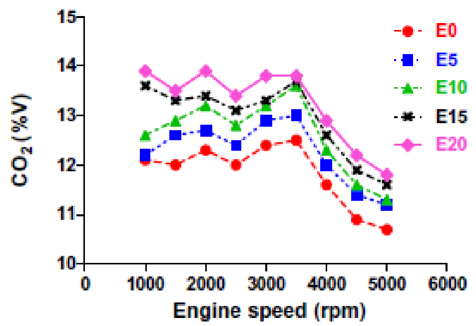


Fig.12.Experimental results of CO_2 at different fuel blends and engine speeds (rpm)

At 3000 rpm, the CO_2 concentration using E5, E10, E15 and E20 was increased by 3.87%, 6.06%, 6.67% and 10.14% respectively in comparison to gasoline. As a result of the lean burning associated with increased ethanol percentages, the CO_2 emission increased because of the improved combustion. It is recorded that CO_2 concentration increased as the ethanol percentage increased. CO_2 emission depends on relative air-fuel ratio and CO emission concentration. At 3000 rpm, the CO_2 concentration using E5, E10, E15 and E20 was increased by 3.87%, 6.06%, 6.76% and 10.14% respectively in comparison to gasoline. As a result of the lean burning associated with increasing ethanol percentages, the CO_2 emission increased because of the improved combustion.

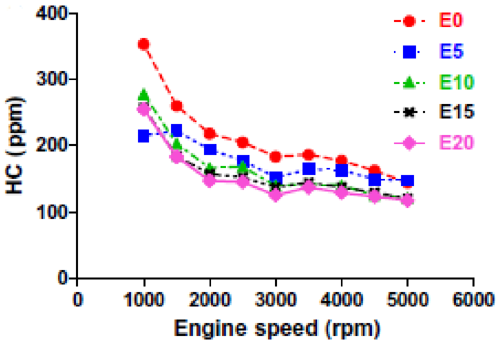


Fig.13.Experimental results of HC at different fuel blends and engine speeds (rpm)

At 3000 rpm, HC concentration using E5, E10, E15 and E20 was decreased by 16.94%, 24.04%, 25.14% and 31.69% respectively in comparison to gasoline. The concentration of HC emission decreased with the increased of the relative air-fuel ratio

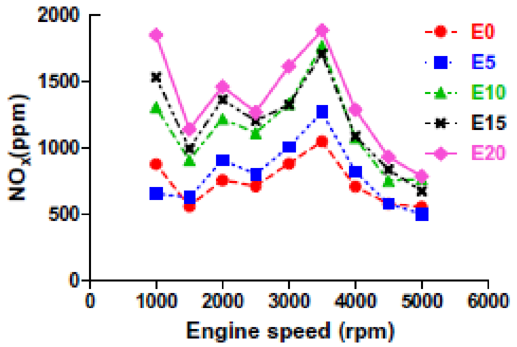


Fig.14.Experimental results of NO_x at different fuel blends and engine speeds (rpm)

It was observed that NO_x concentration is higher when ethanol percentage increased. NO_x concentrations at 3000 rpm using E5, E10, E15 and E20 was increased by 12.57%, 33.94%, 33.6% and 45.55% respectively in comparison to gasoline. When the combustion process is closer to stoichiometric, flame temperature increased, therefore the NO_x emission is increased.

M BCelik[3] used a single-cylinder 4 stroke engine with CR 6:1. To increase the CR of engine, cylinder head was changed and the CR could be raised from 6:1 up to 10:1.

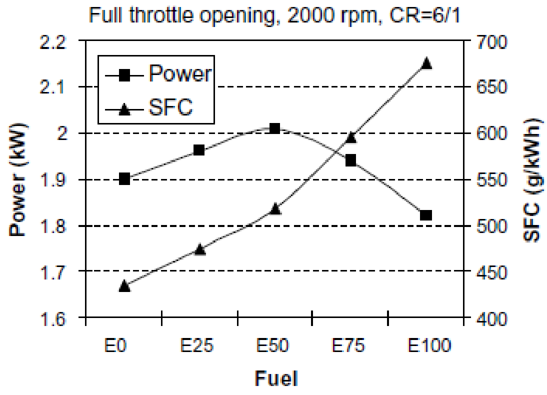


Fig.15. The effect of various fuels on power and SFC

The power increased 3%, 6% and 2% for E25, E50 and E75 fuels respectively as compared to E0 fuel.High heat of evaporationprovides fuel–air charge to cool and density to increase, thus higher power output is achieved as compare to gasoline only.However, powerincrement starts to decrease when ethanol percentageis raised to more than 50%. With the use of E100 fuel, it is observed that a 4% decline in power as compared to E0 fuel.

The heating value of ethanol is lower than gasoline, the SFC increased as the ethanol percentage in blend increased. Increment of 10%, 19%, 37% and 56% in the SFC were recorded with E25, E50, E75 and E100 fuels respectively.

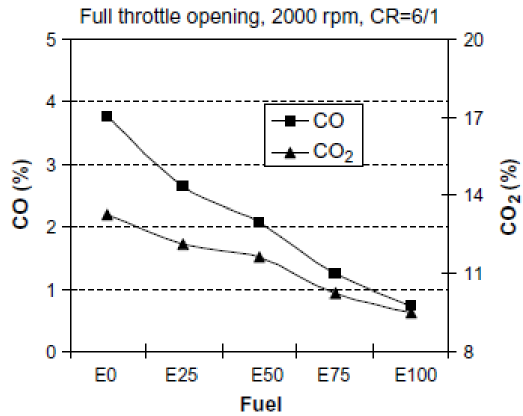


Fig.16. The effect of various fuels on CO and CO_2 emissions

CO is a toxic gas which is produced from incomplete combustion. Reduction in CO emission is due the oxygen content more in ethanol than that of gasoline. With ethanol-gasoline blends, the complete combustion takes place and CO emission is reduced. It was observed that the CO emission values about 3.76%, 2.65%, 2.06%, 1.24% and 0.73% for E0, E25, E50, E75 and E100 fuels respectively.

Carbon dioxide is non-toxic but contributes to the greenhouse effect. It was recorded that the CO_2 emission values about 13.25%, 12.14%, 11.62%, 10.25% and 9.51% with E0, E25, E50, E75 and E100 fuels respectively.

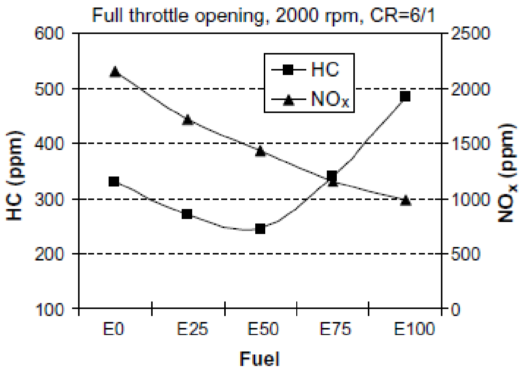


Fig.17. The effect of various fuels on HC and NO_x emissions

It was noticed that the HC emission decreased with the ethanol percentage in the blend increased. It was also observed that the HC emission increased when running with E75 and E100 fuels. As the ethanol percentage in the blend increased, NO_x value decreased.

According to the results of experiment, it was concluded that the most suitable fuel was E50 in terms of power and HC emission. CO, CO_2 and NO_x were low with E100 fuel also.

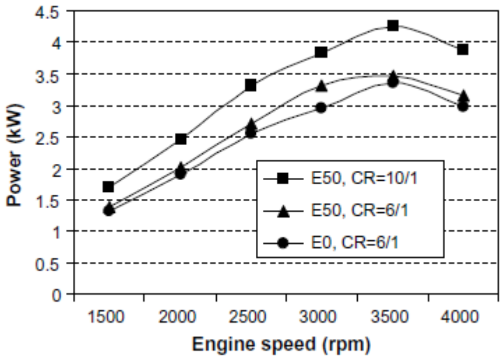


Fig.18. The effect of E0 and E50 fuels on power at various CR

It was observed that the E50 blend produced power about 6% higher than that of E0 blend at CR 6:1. The power increase of 29% with E50 blend without knocking at CR 10:1 as compared to E0 blendsat CR 6:1.

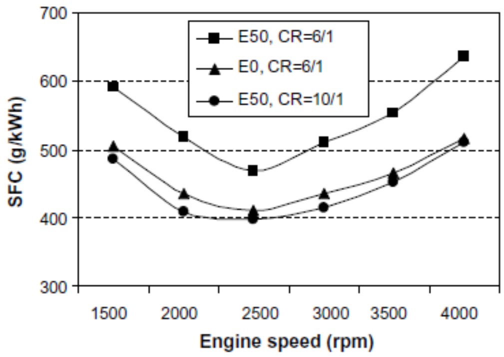


Fig.19. The effect of E0 and E50 fuels on SFC at various compression ratios

The heating value of ethanol is lower than that of gasoline, the SFC increases. It was clearly observed that the SFC increased about 19% with E50 blend at CR 6:1 and decreased about 3% at CR 10:1 as compared to E0.

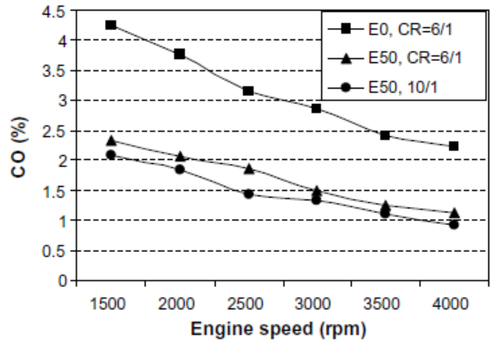


Fig.20. The effect of E0 and E50 fuels on CO emissions at various CR

CO emission recorded from the results that with E50 fuel at the CR 10:1 is about 53% lower than that with E0 fuel at the CR 6:1.

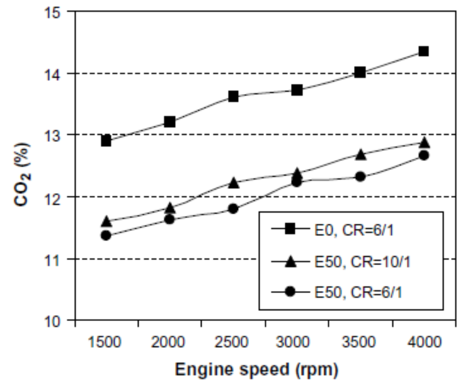


Fig.21. The effect of E0 and E50 fuels on CO_2 emissions at various CR

It was observed that the CO_2 emission with E50 blend at CR 10:1 about 10% lower than that of E0 fuel at CR 6:1. It was also determined that CO_2 increased as CO decreased with increasing engine speed.

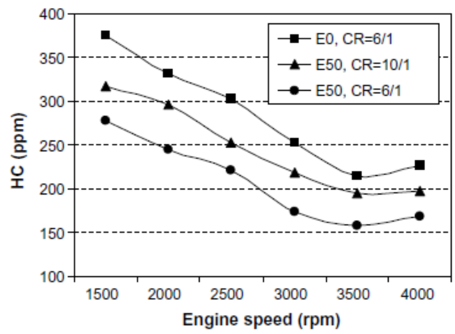


Fig.22. The effect of E0 and E50 fuels on HC emissions at various CR

It was recorded that the HC emission with E50 fuel about 26% lower than that of E0 fuel at CR 6:1, but with increased CR from 6:1 to 10:1, HC emission decreased by about 19%.

As the CR increases, the combustion chamber surface/volume ratio also increased and this, in turn, increased HC. With E50 blend at high CR 10:1, HC decreased about 12% as compared to E0 fuel at CR 6:1.

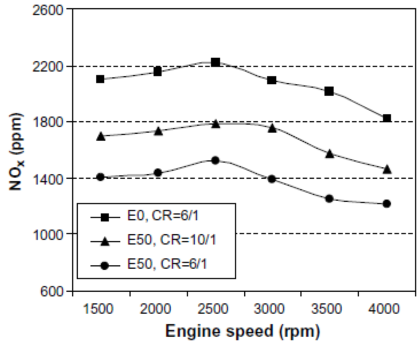


Fig.23. The effect of E0 and E50 fuels on NO_x emissions at various CR

NO_x emission observed with E50 blend at the same CR 6:1 is about 33% lower than that with E0 fuel. For E50 fuel, NO_x increased by about 22% with increasing the CR from 6:1 to 10:1. When running with E50 at high CR 10:1, NO_x decreased by 19% compared to the running with E0 fuel at a CR of 6:1.

HuseyinSerdar[4] used experimental setup, a single cylinder engine with injection type at different speeds (2000, 3000 and 5000 rpm) and at stoichiometric air fuel ratio and at full open throttle.

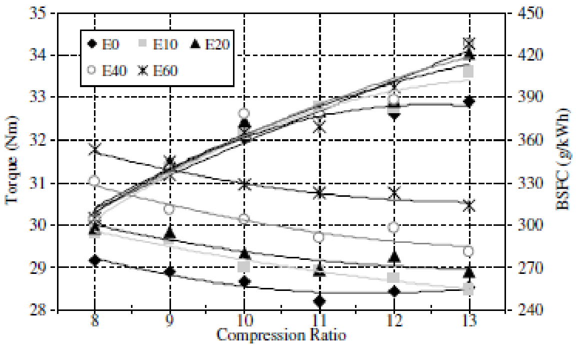


Fig.24. Variation of BSFC and engine torque versus CR (2000 rpm)

With increasing the CR upto 11:1, torque increased ratio about 8% as compared to CR 8:1. Torque increased about .95% with varying the CR from 11:1 to 13:1 as compared to E0.E40 and E60 fuels given highest increased ratio of torque about 14% at CR 13:1 compared with 8:1.

It was recorded that minimum BSFC obtained at CR 11:1 for E40 or E60 as compared to E0 fuel. At CR 8:1, the BSFC decreased about 10% and beyond the CR 11:1 the BSFC increased again. The maximum decrement in BSFC was achieved about 15% with E40 fuel.

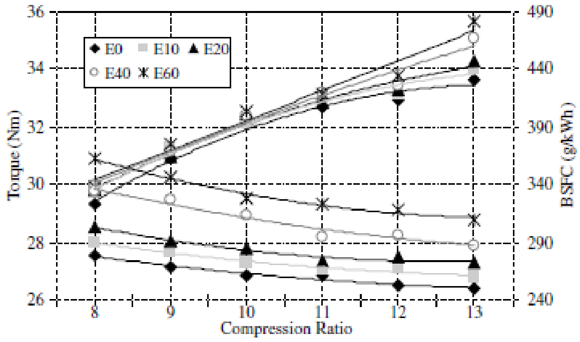


Fig.25. Variation of BSFC and engine torque versus CR (3500 rpm)

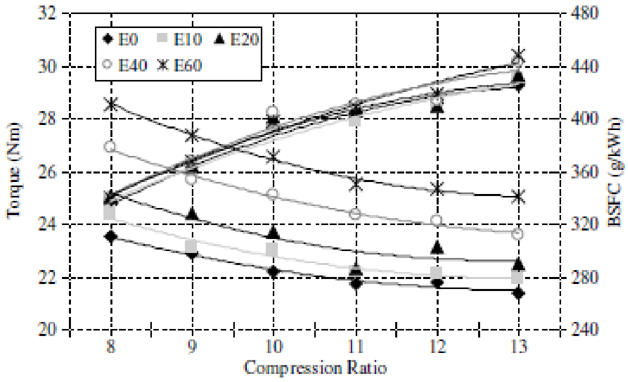
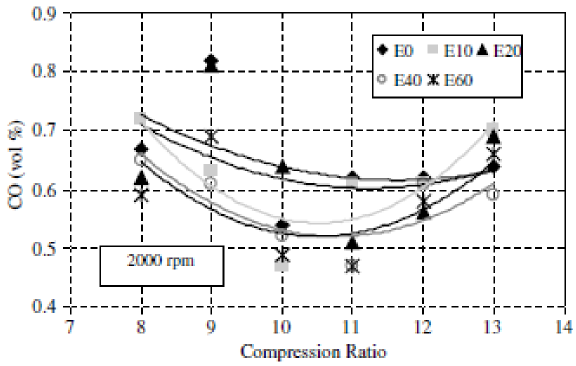


Fig.26. Variation of BSFC and engine torque versus CR (5000 rpm)

It was observed that increasing CR at both engine speeds, torque increased. Torque increased with E0 fuel about 14.6% and 18.4% at 3500 and 5000 rpm respectively at CR 13:1 compared with CR 8:1. With E60 fuel maximum increased torque about 19.2% and 21.5% at 3500 and 5000 rpm respectively.Maximum torque was recorded with E60 fuel by 19.2% and 21.5% at 3500 and 5000 rpm, respectively.

At higher CR 13:1 compared with CR 8:1, BSFC improved with E0 fuel about 10.4% and 13.6% at 3500 and 5000 rpm respectively. With E60 fuel, improved BSFC was about 14.7% and 17% at 3500 and 5000 rpm respectively.



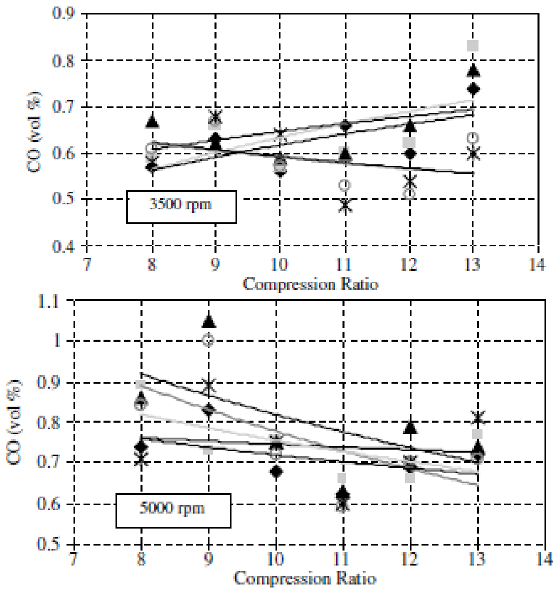


Fig.27. Variation of CO emissions versus CR

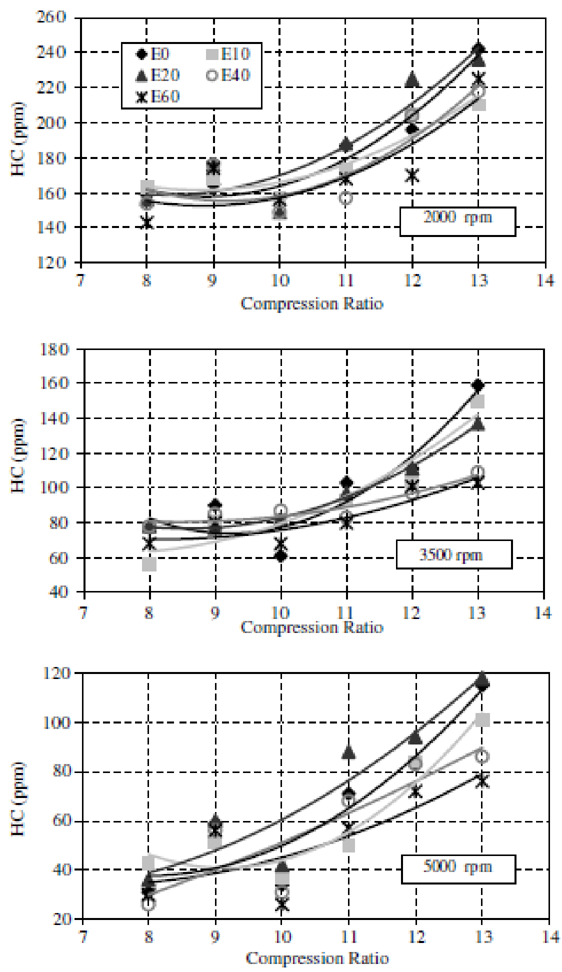


Fig.28. Variation of HC emissions versus CR

The most significant reduction in CO emission was observed with the use of E40 and E60 fuels at 2000 rpm engine speed. Reduction in CO emission wasobserved 11% and 10.8% for E40 and E60 respectively. Highest decrease in HC emission was observed at 5000 rpm as 9.9% and 16.45% for E40 and E60, respectively.

Wei-Dong Hsieh[5] used experimental setup, commercial multi-point injection gasoline engine.

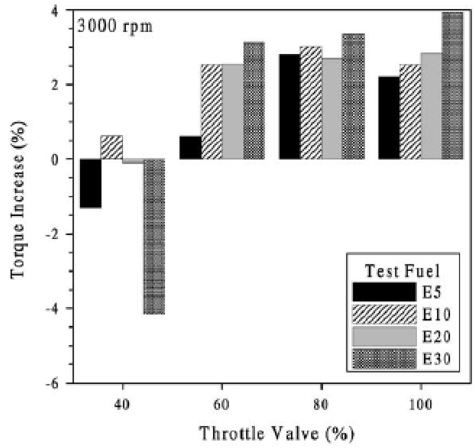


Fig.29. Influence of the blended fuels on the increase of engine torque output (relative to E0) at 3000 rpm.

It was observed that at lower throttle valve openings, torque was either increased or decreased with the addition of ethanol content. The increase of torque grows with the ethanol content ranging from 2% to 4% at higher throttle valve openings(60%, 80% and 100%).

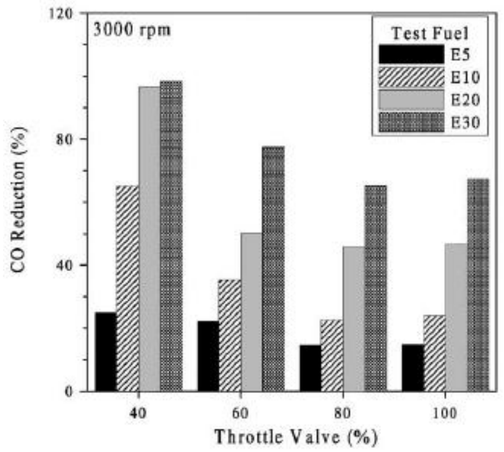


Fig.30. Influence of the blended fuels on the reduction of CO emissions (relative to E0) at 3000 rpm.

Operating condition of the engine effects on CO emission and can be reduced up to 90%.

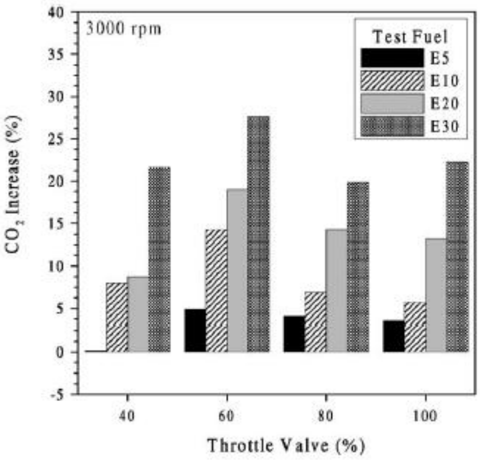


Fig.31. Influence of the blended fuels on the increase of CO_2 emissions (relative to E0) at 3000 rpm

CO_2 emission is increased with addition of ethanol content in the blended fuel. The increase of CO_2 emission grows from 5% to 25% depending on the operating condition and the ethanol content.

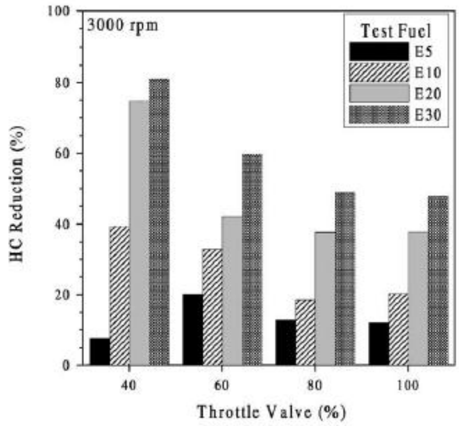


Fig.32. Influence of the blended fuels on the reduction of HC emissions (relative to E0) at 3000 rpm.

The concentration of HC emission decreased from 20% to 80% in comparison with pure gasoline.

Mustafa Canakci[6] were investigated that bsfc of E5 and E10 increasedby 2.8% and 3.6% respectively compared with gasoline. When the vehicle speed was 100km/h, the BSFC of E5 and E10 increased 0.2% and 1.5% respectively compared with gasoline.

Muharrem[7] were investigated the performance and combustion characteristics of a SI engine. The thermal efficiency of E5, E10 increased 1.9% and 2.5% respectively compared to gasoline at 100 km/h.The thermal efficiency for E10 increased 0.4% at 80 km/h and for E5 reduced 0.8% compared with gasoline. This is because E10 fuel blends have more oxygen rate thanE5, the combustion becomes better and so the thermal efficiency increased.

Conclusions

From the literature review it was concluded that:

(I) Engine was produced more torque as compared to gasoline only, for all the speed range. This may because of higher latent heat of evaporation of ethanol.

(II) Blending of ethanol up to 50% in gasoline gives best results in terms of power and HC emissions.
The engine power increased by 29% with E50 fuel at high C.R. compared to E0 fuel.
The lower energy content of ethanol–gasoline blended fuel increased the BSFC, depends on the percentage of ethanol in the blend.
However other emissions are also reduced as compare to gasoline only.
The SFC, CO, CO_2, HC and NO_xemissions were reduced by about 3%, 53%, 10%, 12% and 19%, respectively.

(III) For gasoline fuel as the CR increased, engine power increased & BSFC decreased and HC and NO_x emissions increased.

(IV) It was observed that ethanol–gasoline blended fuel allows increasing compression ratio without knocking.The CO and HC concentrations were decreasedwhile the concentrations ofCO_2 and NO_x were increased when ethanol-gasoline blends are used.

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