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Effects of various ethanol blends in gasoline on variable compression ratio engine

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ABSTRACT

The objective is to determine blend which gives less emission and good performance characteristics, comparing emissions and performance characteristics between blends and pure gasoline fuel at different speeds, different compression ratios and different loads and carry out the test on VCR engine at full throttle valve opening without modification and without knocking at, different gasoline-ethanol blends (E5,E10,E15) and pure gasoline, different compression ratios (8,9,10) and different speeds (1600,1700,1800 in rpm) where, performance characteristics are volumetric efficiency, brake power, brake thermal efficiency and emissions of CO, CO_2, HC.

Introduction

Alcohol fuels particularly ethanol can be produced by fermentation of bio mass crops, mainly sugar cane, wheat and wood. Usage of alcohols and liquefied petroleum gas as a fuel for spark ignition engines has some advantage to compare the gasoline. The engine thermal efficiency can be improved with increasing of compression ratio. Alcohols burns with lower flame temperatures and luminosity owing to decreasing the peak temperature inside the cylinder and hence the heat losses and NOx emissions are lower. The world is presently confronted with crises of fossil fuel depletion [1].

Ethanol, a promising fuel

Among the various alcohols, ethanol is known as the most suited fuel for spark ignition (SI) engine. The most attractive properties of ethanol as an SI engine fuel are that it can be produced from renewable energy sources such as agricultural feedback and it has high octane number and flame speed. Production method and properties of ethanol will be further explained and discussed in the following sections. Ethanol can be used in SI engines as pure or by blending with gasoline. Pure ethanol necessitates some modification on engine design and fuel system whereas it can be used in SI engines by blending with gasoline at low concentration without any modification. It was reported that using gasoline-ethanol blends including ethanol at low concentration could improve engine performance and exhaust emission [2, 3].

VCR Engine

The concept of variable compression ratio (VCR) promises improved engine performance, efficiency and temperatures. During the early part of combustion a small residual gas fraction owing to higher compression ratio gives faster laminar flame speed. Therefore, the ignition delay period is shorter. As a result, at low loads, the greater the compression ratio, the shorter is the combustion time.

The time loss is subsequently reduced. Therefore, it seems reasonable that fuel consumption rate is lower with high compression ratios at part load. The main feature of the VCR engine is to operate at different compression ratios, depending on the vehicle performance needs. A VCR engine can continuously vary the compression ratio by changing the combustion chamber volume. Up to 20% to 30% exhaust emission are reduced; also the fuel economy is increase [1].

Fuel Properties And Experimentation

For blending 99.99% pure ethanol which is produced by 'Analytical CS Reagent' and gasoline are used.

Preparation of Blend

For the presented work the different blends of gasoline and ethanol are used. They are E0, E5, E10 and E15 the number following E indicates percentage of volumetric amount of ethanol in gasoline.

These blends are prepared for two liters of each category. The ethanol used for blend preparation is 99.9% pure and the properties are given by the supplier in the test report provided.

Figure 1. Blend Preparation

Properties of Blends

The properties of blended fuels are determined at the beginning of the experiment.

Fuel property	Gasoline	Ethanol
Density (kg/m^3)	765	785
Latent heating value (MJ/kg)	44000	26900
Stoichiometric air/fuel ratio	15.2	9
Research octane number	91	108.6
Motor octane number	85	89.7
Molecular weight (kg/kmol)	114.18	46.07
Molar C/H ratio	305	840

Table 1: Gasoline and Ethanol Properties [4]

If the properties of the pure gasoline and ethanol are known, the properties of the blended fuels are calculated as follows:

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$$\rho bl = \frac{Xg\rho g + Xe\rho e}{100}$$

$$(^{A}/_{F})bl = \frac{Xg\rho g(A/F)g + Xe\rho e(A/F)e}{Xg\rho g + Xe\rho e}$$

$$(RON)bl = \frac{Xg\rho g(RON)g + Xe\rho e(ROL)e}{Xg\rho g + Xe\rho e}$$

$$(RON)bl = \frac{Xg\rho g(RON)g + Xe\rho e(ROL)e}{Xg\rho g + Xe\rho e}$$

$$(MON)bl = \frac{Xg\rho g(MON)g + Xe\rho e(MOL)e}{Xg\rho g + Xe\rho e}$$

$$(MW)bl = \frac{Xg\rho g(MW)g + Xe\rho e(MW)e}{Xg\rho g + Xe\rho e}$$

$$(MR)bl = \frac{Xg\rho g(MR)g + Xe\rho e(MR)e}{Xg\rho g + Xe\rho e}$$

Where, g and e subscript used for gasoline and ethanol, bl subscript used for blend, X_g and X_e are percentage of gasoline and ethanol in blend respectively and ρ_g and ρ_e are density of gasoline and ethanol respectively [5, 6].

Table 2: Blend Properties

Fuel property	E5	E10	E15
Density (kg/m³)	766.25	767.5	768.75
Latent heating value (MJ/kg)	14.88	14.56	14.24
Stoichiometric air/fuel ratio	43118.5	42239.9	41364.1
Research octane number	91.90	92.81	93.71
Motor octane number	85.24	85.48	85.72
Molecular weight (kg/kmol)	110.67	107.17	103.68
Molar C/H ratio	332.58	360.06	387.47

Engine Test Set Up

The setup consist up of single cylinder, four stroke, multi-fuel, research engine connected to eddy current type dynamometer for loading as shown in the figure 2. The operation mode of the engine can be changed from diesel to petrol or from petrol to diesel with some necessary changes. In both modes of compression ratio can be varied without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. The injection point and spark point can be changed for research tests. Setup is provided with necessary instruments for combustion pressure, diesel line pressure and crank- angle measurements. These signals are interfaced with computer for pressure crank- angle diagrams [7].

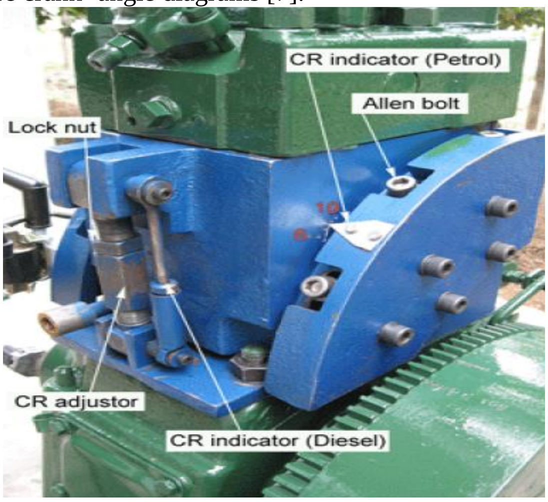

Figure 2: Test Set Up

Experimental Procedure

The tests were performed at full throttle opening and compression ratios were varied as 8:1, 9:1 and 10:1. The speed range considered was 1600 to 1800 rpm; by the increment of 100 rpm. All the necessary parameters were measured and recorded by the computer using "engine soft" software. The exhaust emissions were measured for each case of speed using an exhaust gas analyzer. The above procedure was repeated for each of the blended fuels E0, E5, E10, and E15 [8].

Figure 3: Experimental Run

Observations and Readings

Readings table for emission of gases at 1800 rpm:

Blends	C.R.	CO(%)	CO_2(%)	HC(ppm)
E0	8	9.0454	11.8310	612.50
	9	7.6410	12.0803	462.51
	10	7.0909	12.5001	337.53
E05	8	8.2720	11.0800	600.00
	9	7.0909	11.5131	425.00
	10	6.8181	12.0276	300.00
E10	8	7.409	10.6385	525.00
	9	6.5454	11.2510	381.25
	10	6.2728	11.3890	225.00
E15	8	6.4363	10.3301	581.25
	9	6.1090	10.2191	462.51
	10	4.8880	11.1166	250.00

Readings table for emission of gases at 1600 rpm, 1700 rpm and 1800 rpm:

Emissions	Blends	Speed		
		1600	1700	1800
CO(%)	E0,C.R.-8	8.05	7.71	7.55
	E10,C.R.-8	7.60	7.42	7.3571
	E10,C.R.-10	6.85	6.71	6.60
CO_2(%)	E0,C.R.-8	4.0909	4.1818	4.2727
	E10,C.R.-8	3.58	3.65	3.82
	E10,C.R.-10	7.0	7.1363	8.0909
HC(ppm)	E0,C.R.-8	694.444	666.667	650
	E10,C.R.-8	555.55	511.11	483.333
	E10,C.R.-10	266.67	244.44	222.22

Results And Discussion

The tests were conducted for various blends from E0 (i.e. pure gasoline) to E15 with additional 5% ethanol during each test. The different engine speeds considered as 1600 rpm, 1700 rpm and 1800 rpm. The compression ratio was varied as 8, 9 and 10. The test results are summarized as below.

The Engine Performance with Various Blends

The variations in different performance parameters like BSFC, BP, BTHE and engine exhaust emission like CO, CO_2 and HC for various blends are shown in coming figures.

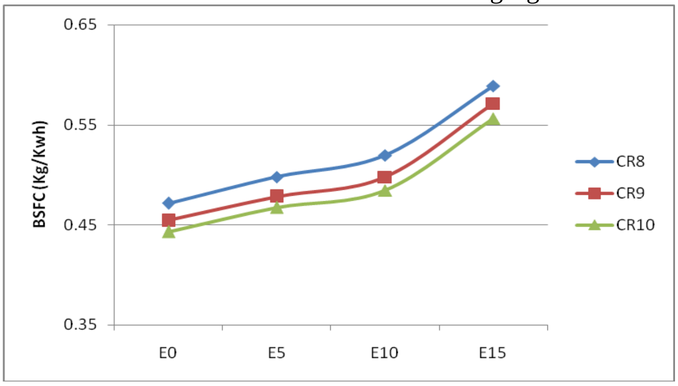

Figure 4: Effect of various blends on brake specific fuel consumption at constant speed (at wide throttle opening)

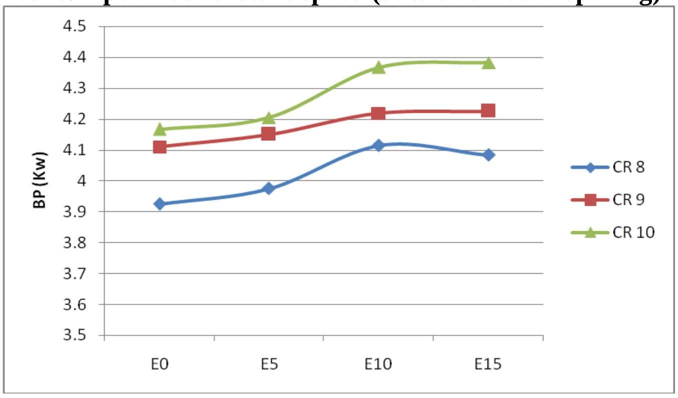

Figure 5: Effect of various fuels on brake power at constant speed (at full throttle opening)

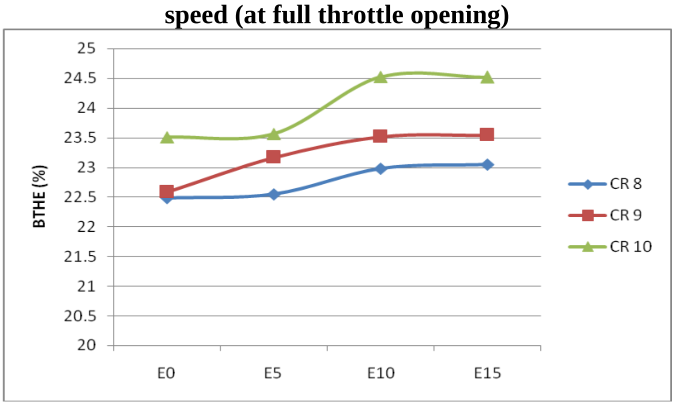

Figure 6: Effect of various fuels on brake thermal efficiency at constant speed (at wide throttle opening)

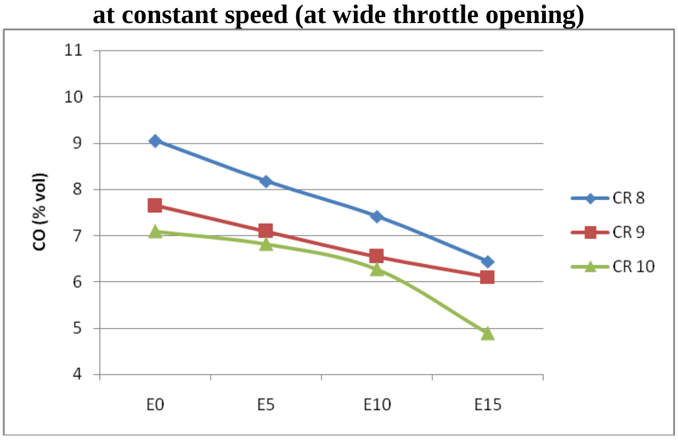

Figure 7: Effect of various fuels on CO emission at constant speed

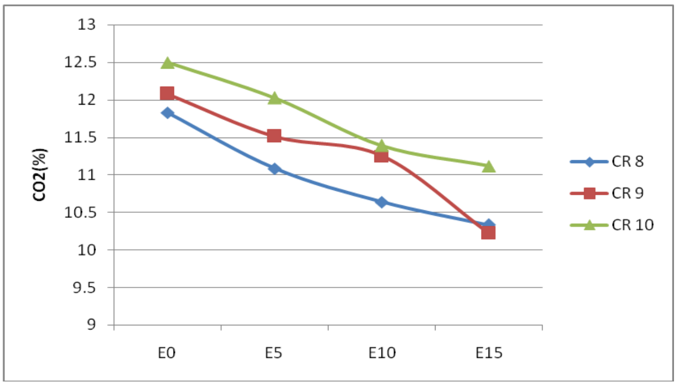

Figure 8: Effect of various fuels on CO_2 emission at constant speed (at full throttle opening)

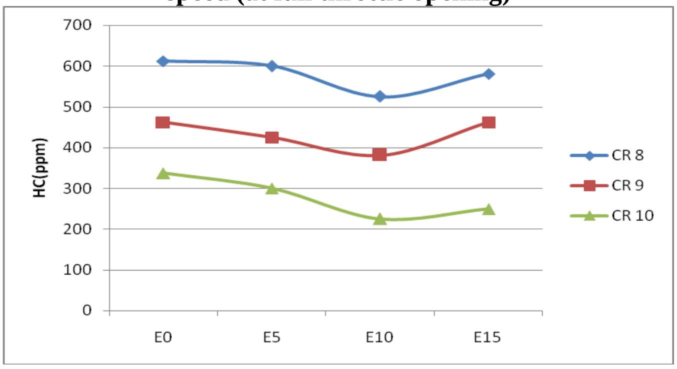

Figure 9: Effect of various fuels on HC emission at constant speed (at full throttle opening)

Comparison of E0 and E10 on the fuels on the basis of engine performance

The effect of E0 and E10 fuels on the performance parameters like BSFC, BP, BTHE and engine exhaust emission like CO, CO_2 and HC are shown in coming figures.

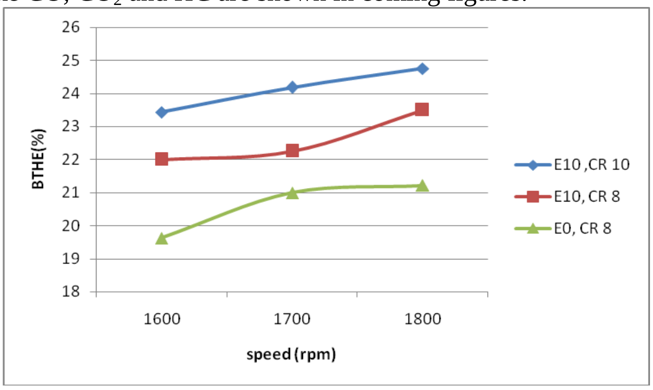

Figure 10: Effect of E0 and E10 fuels on brake thermal efficiency at various compression ratios

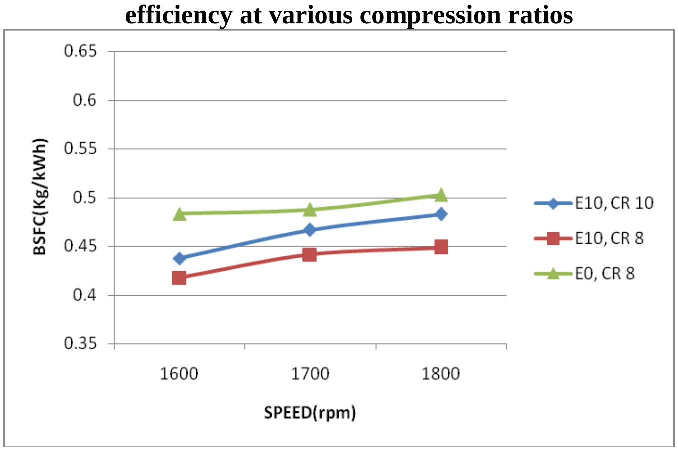

Figure 11. Effect of E0 and E10 fuels on brake thermal efficiency at various compression ratios

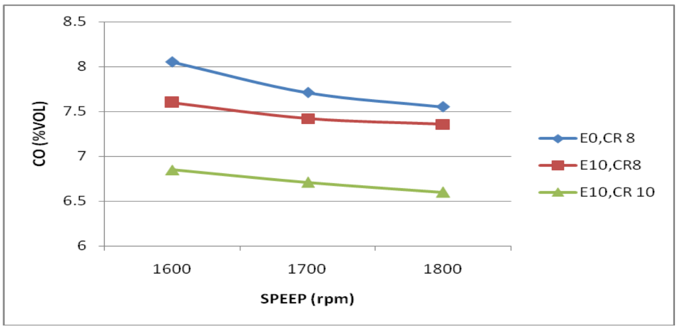

Figure 12: Effect of E0 and E10 fuels on CO at various compression ratios

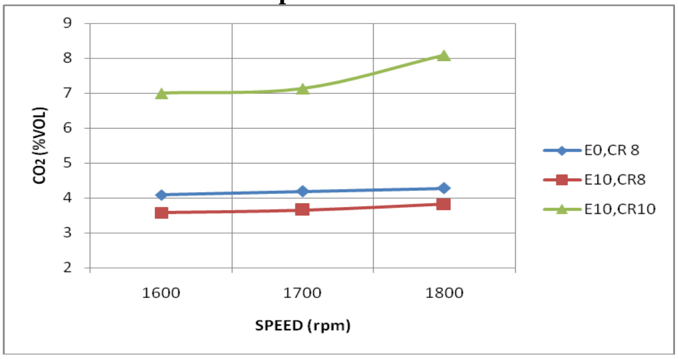

Figure 13: Effect of E0 and E10 fuels on CO_2 at various compression ratios

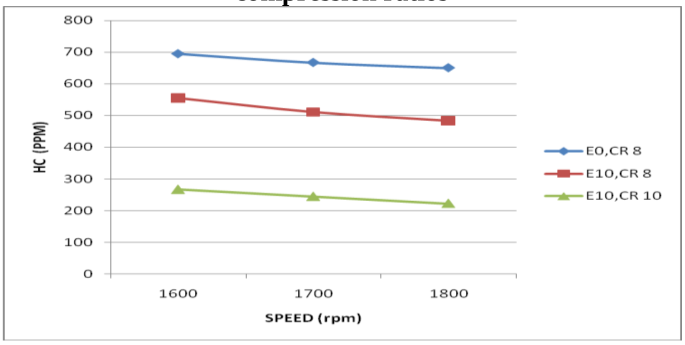

Figure 14: Effect of E0 and E10 fuels on HC at various compression ratios.

Conclusions

Efficiency with the blended fuels is found to be 1.3% to 4.7% higher than that of pure gasoline in all speed range due to higher latent heat of evaporation of ethanol. The lower energy content of blended fuels caused increment up to 27% in brake specific fuel consumption of the engine depending on percentage of ethanol in the blend. A significant reduction in CO emission up to 13% is observed due to oxygen enrichment resulting from ethanol. HC emission decreased up to 25% decrease with increases in speed and compression ratio for blended fuels. E10 is to be found best suitable blend as after which a decrease in the heating value causes increase in brake specific fuel consumption. As the compression ratio increases up to 10:1, a decrease in brake specific fuel consumption up to 3% is achieved for E10 as compared with E0 beside lower heating value of E10. Exhaust gas temperature are found to be decreased with increase in percentage of ethanol and also with increase in compression ratios.

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