INTERNATIONAL JOURNAL OF
ENERGY AND ENVIRONMENT

Volume 1, Issue 5, 2010 pp.861-870
Journal homepage: www.IJEE.IEEFoundation.org

Efficiency and exhaust gas analysis of variable compression ratio spark ignition engine fuelled with alternative fuels

N. Seshaiah

Professor of Mechanical Engg., M.I.T.S, Madanapalle, Angallu-517325, A.P, India.

Abstract
Considering energy crises and pollution problems today, investigations have been concentrated on decreasing fuel consumption by using alternative fuels and on lowering the concentration of toxic components in combustion products. In the present work, the variable compression ratio spark ignition engine designed to run on gasoline has been tested with pure gasoline, LPG (Isobutene), and gasoline blended with ethanol 10%, 15%, 25% and 35% by volume. Also, the gasoline mixed with kerosene at 15%, 25% and 35% by volume without any engine modifications has been tested and presented the result. Brake thermal and volumetric efficiency variation with brake load is compared and presented. CO and CO_2 emissions have been also compared for all tested fuels.

Keywords: SIE, Pollution, Kerosene, Ethanol, LPG, Alternative fuels.

1. Introduction

The world is presently confronted with the twin crises of fossil fuel depletion and environmental degradation. Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction in underground-based carbon resources. 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.

Huseyin *et al* [1-3] studied the effect of ethanol gasoline blends on spark ignition engine performance and exhaust gas emissions at different compression ratios. In their study, test fuels were prepared using 99.9% pure ethanol and gasoline blend with the volumetric ratios of 0 to 30%. A comparative evaluation of the performance characteristics of a spark ignition engine using hydrogen and compressed natural gas as a alternative fuel by Das *et al* [4].It has been observed in their study that the brake specific fuel consumption was reduced and the brake thermal efficiency improved with hydrogen operation compared to the system running on compressed natural gas. Using ethanol as a fuel additive to unleaded gasoline causes an improvement in engine performance and exhaust emissions [5].

Sridhar *et al* [6] investigated on a commercially available diesel engine so as to explore the possibility of working at the existing CR of 17:1 and optimising the same. On the onset of investigation, it was perceived that increase in CR could have conflicting effects on the power output of the engine. Ethanol-diesel blends up to 20% can very well be used in present day constant speed CI engines without any hardware modifications [7]. Exhaust gas temperature and lubricating oil temperature were lower for ethanol-diesel blends than mineral diesel. Also significant reduction in CO, NO_x emission was observed while using ethanol-diesel blends. Spark ignition engine performance [8] with power gas fuel which is a mixture of CO/H2 and compared the results with gasoline and natural gas at similar conditions. De Boer et al [9] have given a description of the difference between hydrogen engine and engines running on hydrocarbons. Tzeng, *et al* [10] evaluated the best alternative fuel for buses suitable for the urban area to explore the potential direction development in the future.

2. Experimental procedure and equipment

The internal combustion engine performance is generally indicated by the term efficiency (η). The break thermal efficiency (η_{bth}) and mechanical efficiency of the engine (η_m). These two important parameters apart from exhaust gas analysis have been aimed at in this study. Performance and exhaust gas analysis of variable compression ratio spark ignition engine, which has been designed for gasoline, is tested with ethanol blended with gasoline at different proportions. Similarly, the engine also has been tested with gasoline blended with kerosene at different proportions by volume. Later the separate attachment for liquefied petroleum gas without modifications of the engine has set and performance of the engine has made.

The objective is to asses whether satisfactory performance and low emissions can be achieved relatively or not. In the experimental study, a single cylinder (Mak-25) variable compression ratio spark ignition engine was used. Typical views of test engine have shown in Figure 1 and Figure 2. The specifications of test engine are shown in Table 1 and the properties of the fuels used are shown in Table 2. The tests were performed keeping the speed constant at 2400 rpm at all loads. The test fuels used are gasoline, liquefied petroleum gas, gasoline and ethanol blends (10%, 15%, 25%, and 35%, of ethanol with gasoline by volume). Also, the gasoline is blended with kerosene at different proportions by volume (K15, K25, and K35). The experiment was performed at four different compression ratios (4.6:1, 6:1, 8:1, 9:1) for each fuel and the effect of engine performance was investigated. The engine to be tested was started and allowed to run at no load for about 30 minutes to reach the steady state for each fuel to be tested.

Air consumption was measured with orifice meter and the liquid fuel consumption was measured with burette. Gas flow meter is used to measure the flow rate of gaseous fuels (LPG). Fuel consumption, temperature at corresponding positions, rpm, and exhaust gas temperature were noted for no load condition. After this the engine was loaded in steps and corresponding data for each load was noted. Exhaust gas analysis has been done with the help of Orsat apparatus and measured carbon monoxide and carbon dioxide emissions when the above said different fuels used and comparative statement has been made.

Figure 1. Photograph of experimental test rig

Table 1. Principal specifications of test engine

S.No	Specification	Value
1	BHP (Mak-25)	2.5
2	Rated speed	3000 RPM
3	Number of cylinders	1
4	Compression Ratio	2.5:1 TO 10:1
5	Bore	70 mm
6	Stroke length	66.7 mm
7	Type of ignition	Spark ignition
8	Method of loading	Eddy current dynamometer
9	Method of starting	Crank start
10	Method of cooling	Air cooled

Table 2. Important physical properties of pure and blended fuels used for testing

S.NO	Fuel	Density (kg/m^3)	Calorific Value (kJ/kg)
1	Petrol	740 at 293K	43932
2	Ethanol	785	30000
3	Kerosene	780 at 313K	45400
4	LPG	2.0 at 273K & 1atm.	46400
5	Petrol+E10	768	42185
6	Petrol+E15	770.75	41305
7	Petrol+E25	773.7	39540
8	Petrol+E35	777.19	37760
9	Petrol+K15	746	44152.2
10	Petrol+K25	750	44299
11	Petrol+K35	754	44445.8

3. Results and discussions

The effect of alcohol (ethanol) and gasoline blends, gasoline and kerosene blends on engine performance was investigated. Similarly, the flue gas analysis has been done for all the fuels and compared the results. Brake thermal efficiency and volumetric efficiency of the spark ignition engine at different compression ratio and at constant speed is analysed. Variation of engine brake thermal efficiency with different pure and blended fuels has been compared at constant speed and at different load conditions as shown in Figure 2 to Figure 5. The engine has been tested with petrol, LPG and petrol blended with ethanol and Kerosene at different proportions. Relatively the brake thermal efficiency is less for all the fuels due to low load conditions because of practical limitations on the research engine. The variation is similar for all the engines, and highest efficiency is seen with pure petrol and petrol, ethanol mixture at 35% by volume (E35).The lowest brake thermal efficiency is with K35.This may be due to incomplete combustion of kerosene part. The same type of tendency is observed at all tested compression ratios are in Figure 3 to Figure 5.

Variation of volumetric efficiency with torque is shown in Figures (6 – 9). For all compression ratios, the volumetric efficiency is increasing with load. The highest volumetric efficiency is seen with LPG as a fuel. This is attributed to be the proper mixing of the fuel and air. As the calorific value of the LPG is more, the amount of fuel required per cycle may be is less and hence the requirement of oxygen may be less. The variation of volumetric efficiency at all compression ratios for all the fuels used is with in 6%. This indicates that the volumetric efficiency variation with different fuels more or less constant.

The exhaust emissions of CO and CO_2 gas of the engine at different compression ratios at a particular load and at constant rotational speed is measured and presented in the form of bar charts as shown in Figure 10 and Figure 11. It is clearly seen that the Carbon monoxide emission is highest, when the engine is working with petrol blended with 35% kerosene (by volume), and lowest when working with LPG. This may be due to incomplete combustion of kerosene and complete combustion, when the LPG is used as a fuel. The values for other fuels are in between LPG and petrol and K35. The carbon monoxide emission is reducing with increasing compression ratio. Similarly, the Carbon dioxide emission is shown in Figure 11. The variation of carbon dioxide emission is also highest for petrol with K35 and lowest for pure petrol. The carbon dioxide emission is reducing with increase in compression ratio. This is attributed that at higher compression ratio, combustion process is better due to high temperature at constant speed.

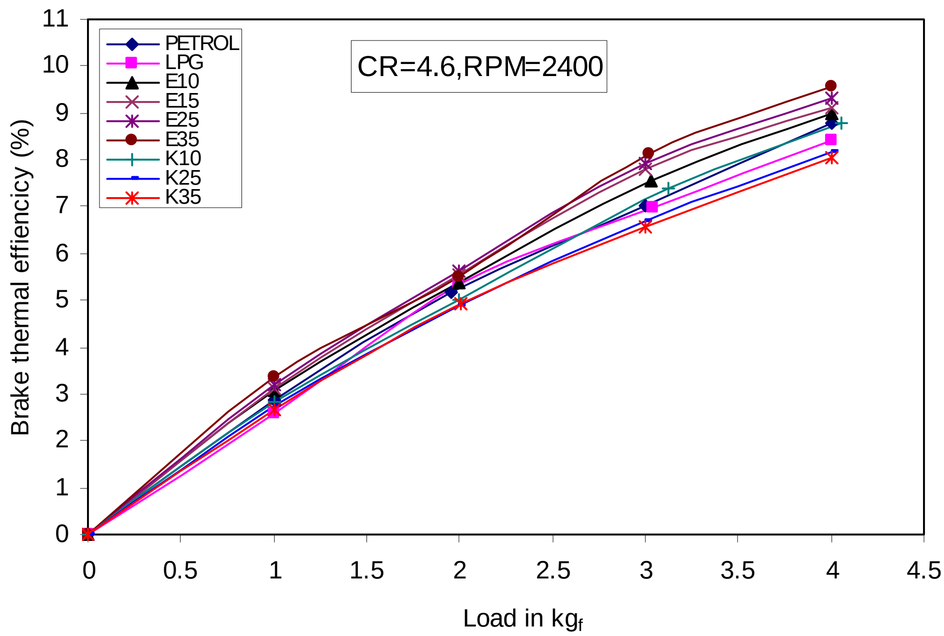

Figure 2. Variation of brake thermal efficiency with load at a constant speed with different pure and blended fuels at CR = 4.6

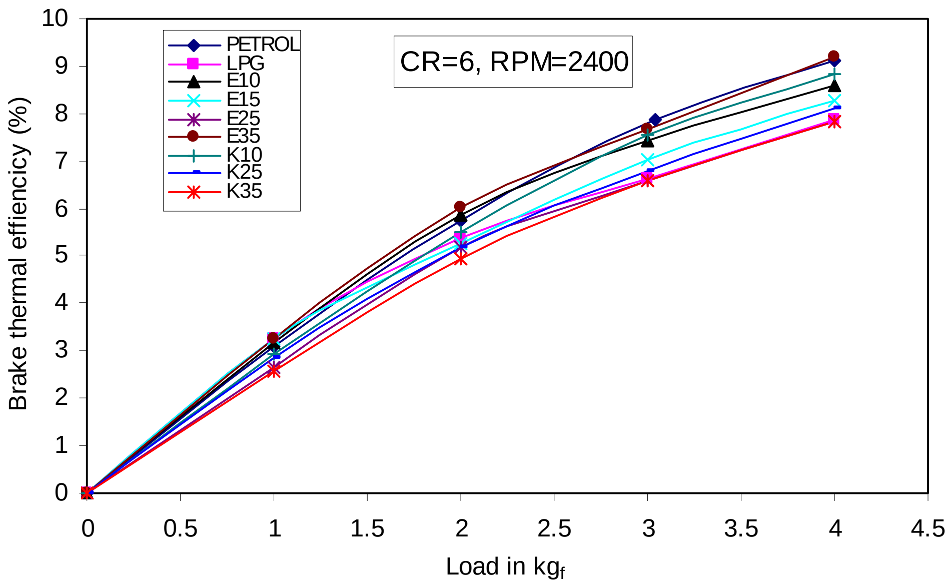

Figure 3. Variation of brake thermal efficiency with load at a constant speed with different pure and blended fuels at CR = 6

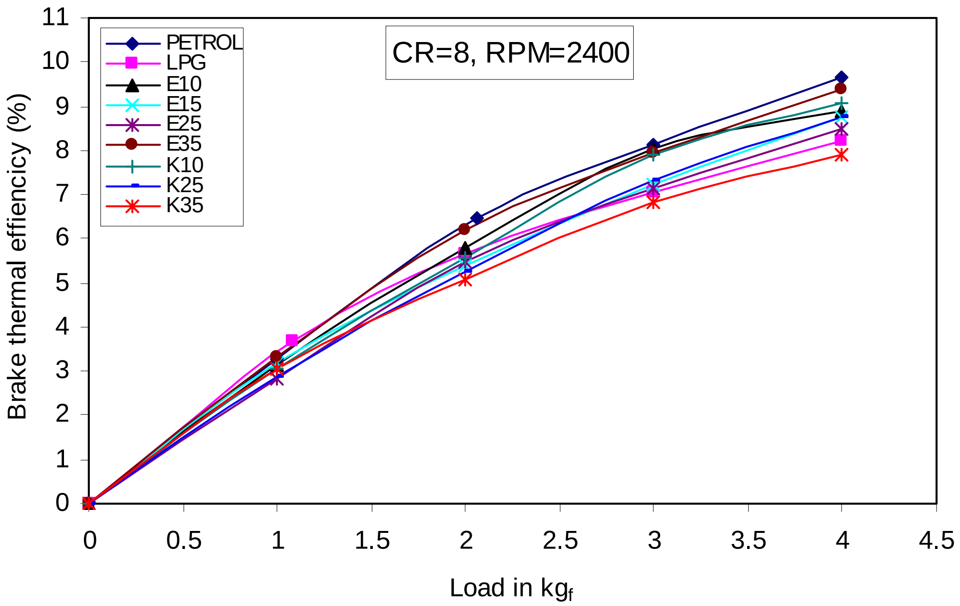

Figure 4. Variation of brake thermal efficiency with load at a constant speed with different pure and blended fuels at CR = 8

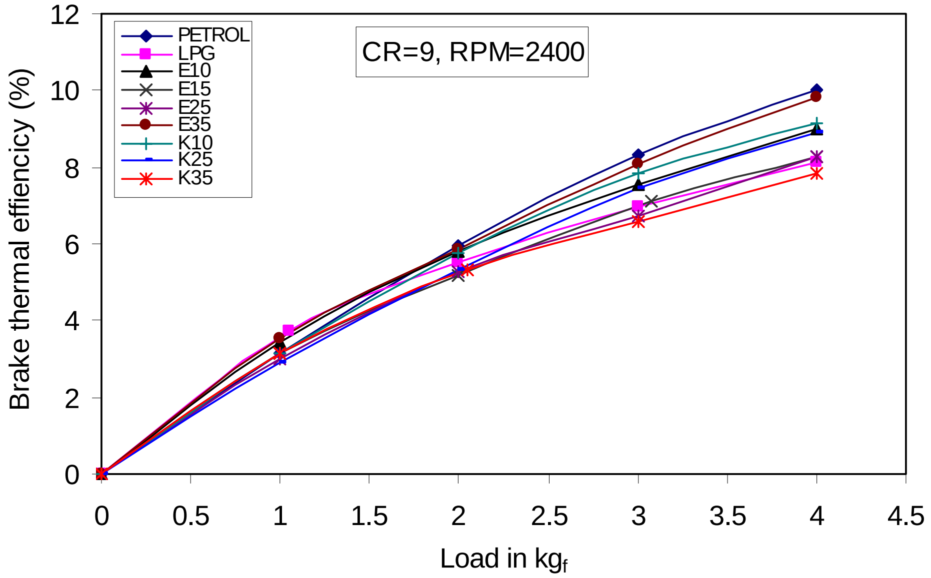

Figure 5. Variation of brake thermal efficiency with load at a constant speed with different pure and blended fuels at CR = 9

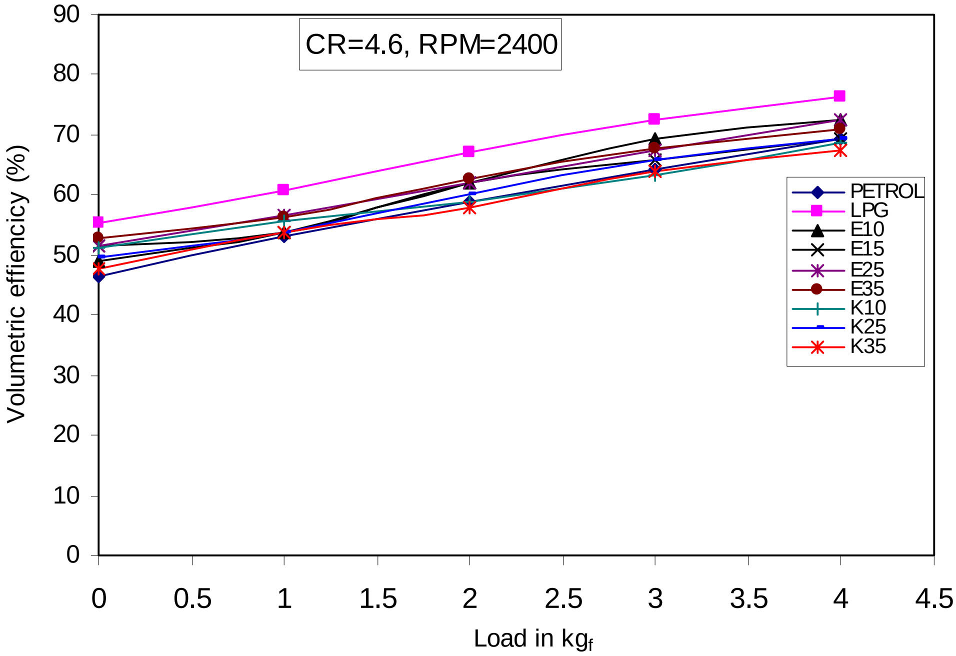

Figure 6. Variation of volumetric efficiency with load at a constant speed with different pure and blended fuels at CR = 4.6

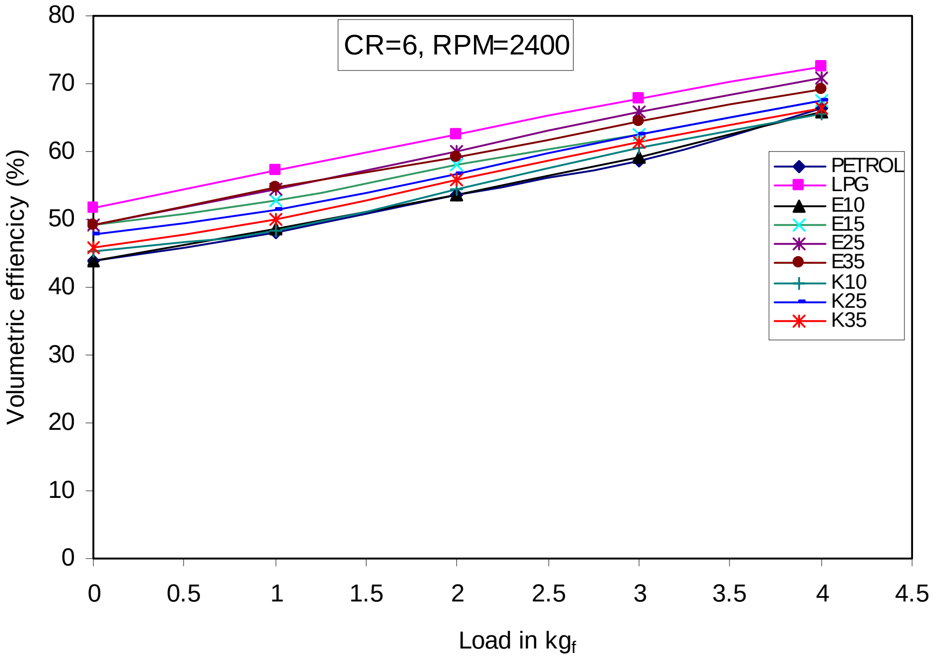

Figure 7. Variation of volumetric efficiency with load at a constant speed with different pure and blended fuels at CR = 6

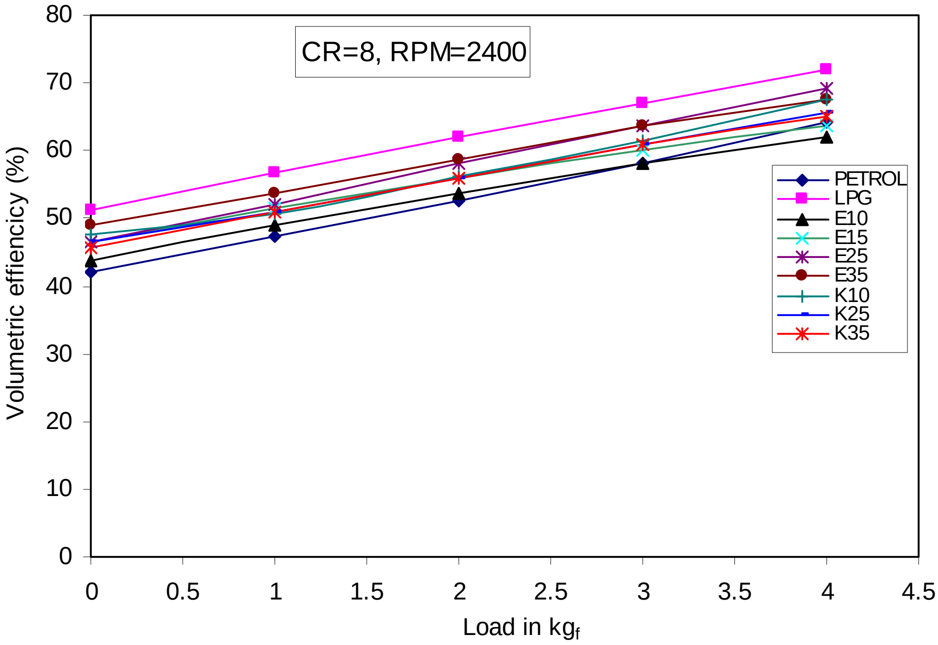

Figure 8. Variation of volumetric efficiency with load at a constant speed with different pure and blended fuels at CR = 8

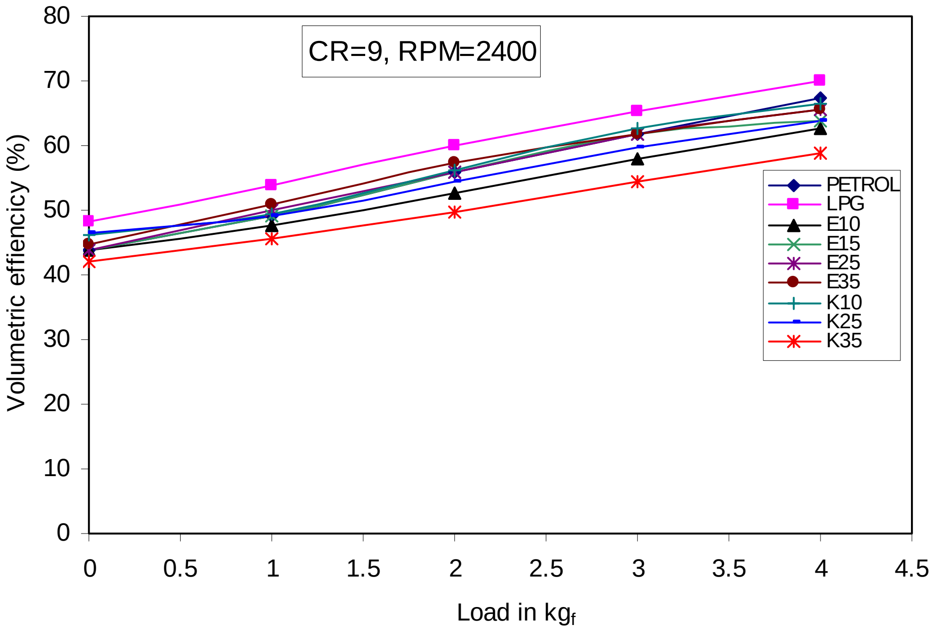

Figure 9. Variation of volumetric efficiency with load at a constant speed with different pure and blended fuels at CR = 9

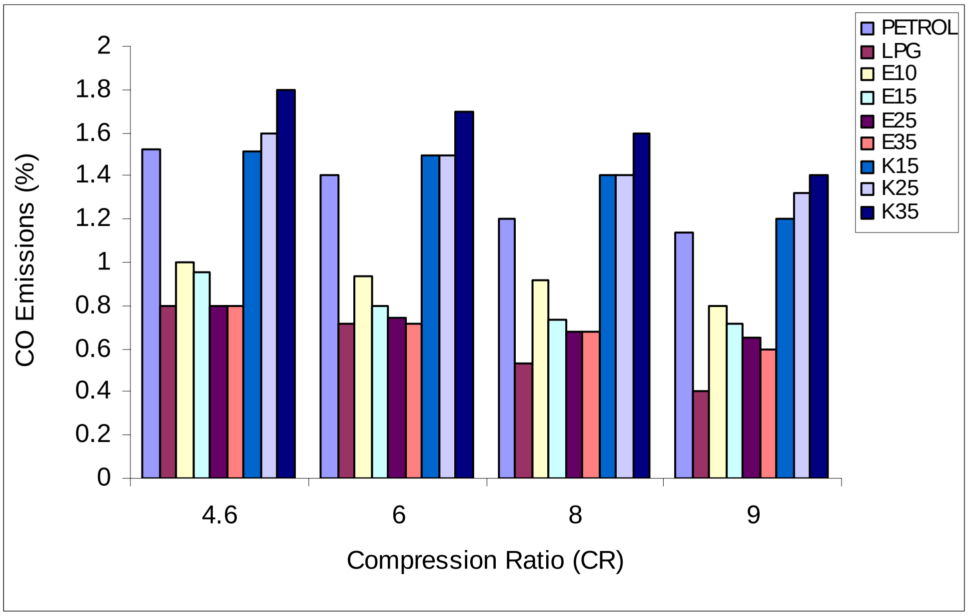

Figure10. Variation of carbon monoxide emission at constant speed and 4.5 kg_f load when the engine is tested at different compression ratios with different pure and blended fuels

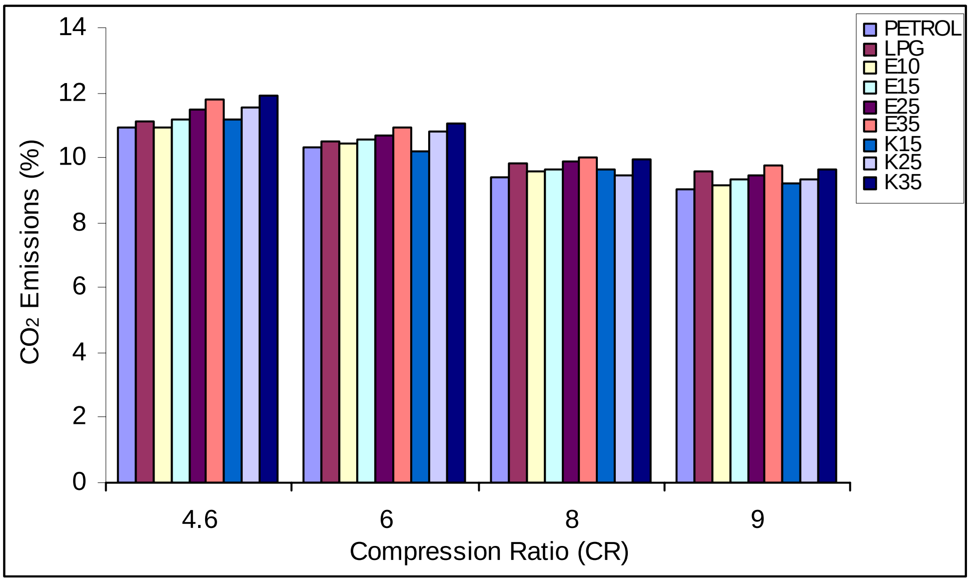

Figure11. Variation of carbon dioxide emission at constant speed and 4.5 kg_f load when the engine is tested at different compression ratios with different pure and blended fuels

4. Conclusion

The variable compression ratio spark ignition engine designed to run on gasoline has been tested with pure gasoline, LPG (Isobutene), and gasoline mixed with ethanol. Also, the gasoline mixed with kerosene at different proportions by volume without any engine modifications has been tested and presented the result. The engine has been tested with pure petrol, LPG, and petrol blended with ethanol 10%, 15%, 25% and 35% by volume. Also the petrol is blended with Kerosene at 15%, 25% and 35% by volume. Brake thermal and volumetric efficiency variation with brake load is compared and presented.
It is observed that the LPG is a promising fuel at all loads lesser carbon monoxide emission compared with other fuels tested. Using ethanol as a fuel additive to the mineral gasoline, (up to 30% by volume) without any engine modification and without any loses of efficiency. It has been observed that the petrol

mixed with ethanol at 10% by volume better at all loads and compression ratios. It also been observed that the variation in thermal efficiency for all the tested fuels is approximately 5%, and well within the experimental error. At medium loads, the efficiency variation is small. It is recommended that the petrol should not mix with the commercially available kerosene as it gives high carbon monoxide emission.

References

[1] Yecesu, H.S; Sozen, A; Topgul, T; Arcaklioglu, E; Comparative study of Mathematical and Experimental analysis of spark ignition engine performance using ethanol-gasoline blend fuel, Applied Thermal Engineering, Vol.27; (2007); pp 358-368

[2] Topgul, T; Yecesu, H.S; Cinar, C; Koca, A; Effect of ethanol-unleaded gasoline blends and ignition timing on engine performance and exhaust emissions; Renewable Energy; Vol.31,(2006); pp 2534-2542.

[3] Yecesu, H.S; Topgul, T; Cinar, C; Okur, M; Effect of ethanol-gasoline blends on engine performance in different compression ratios, Applied Thermal Engineering Vol.26; (2006); pp 2272-2278.

[4] Das, L. M.; Rohit Gulati; Gupta, P. K.; A comparative evaluation of the performance characteristics of a spark ignition engine using hydrogen and compressed natural gas as alternative, International Journal of Hydrogen Energy, Vol. 25, Issue 8, (August 2000), pp 783-793

[5] Agarwal, A.K; Bio fuels (alcohols and bio-diesel) applications as fuels for internal combustion engines, Progress in Energy and Combustion Science, (2006) pp 1-39.

[6] Sridhar, G.; Paul, P.J.; Mukunda, H.S; Bio mass derived Producer gas as a reciprocating engine fuel an experimental analysis, Bio mass and bio engineering, Vol.21, , (July, 2001), pp 61-72

[7] Crookes, R.J; Comparative Bio fuel performance in Internal combustion Engines, Biomass and Bioenergy; Vol.30, issue 5, (2006), pp 461-468.

[8] Mustafi, N.N; Miraglia, Y.C; Raine, R.R; Bansal, P.K; Elder, S.T; Spark ignition engine performance with power gas fuel (mixture of Co/H2) a comparison with gasoline and natural gas, Fuel Journal, Fuel 85, (2006), pp 1605-1612

[9] De Boer, P. C. T.; McLean, W. J.; Homan, H. S.; Performance and emissions of hydrogen fuelled internal combustion engines, International Journal of Hydrogen Energy, Vol.1, (2),(1976), pp153-172

[10] Tzeng, G.H; Lin, C.W; and Opricovic, S; Multi-criteria analysis of alternative-fuel buses for public transportation, Energy Policy, Vol. 33, (2005), pp 1373-1383.

N. Seshaiah received his B.Tech (1988) in mechanical engineering from the JNTU, Hyderabad, ME/M.Tech (1994) in Thermal Science from the MS Universtiy of Baroda, Vadodara, and Ph.D. (2006) degree in Cryogenics from the NIT,Rourkela. His research interests include compression and expansion machinery, computational fluid dynamics, and heat transfer.
E-mail address: seshuet@yahoo.com, Ph.No: 09440203350, Fax: 918672-241387