**International Journal of Advances in Engineering Research** http://www.ijaer.com/
(IJAER) 2011, Vol. No. 2, Issue No. VI, December **ISSN: 2231-5152**

# COMPARATIVE STUDIES ON PERFORMANCE EVALUATION OF FOUR STROKE COPPER COATED SPARK IGNITION ENGINE WITH CATALYTIC CONVERTER WITH ALCOHOLS

**M.V.S. Murali Krishna[1*], K.Kishor[2], Dr.P.V.K.Murthy[3], A.V.S.S.K.S. Gupta[4] , S. Narasimha Kumar[5]**

[1,2,5] *Mechanical Engineering Department, Chaitanya Bharathi Institute of Technology, Gandipet, Hyderabad- 500 075, **

[3] *Vivekananda Institute of Science and Information Technology, Shadnagar, Mahabubnagar*-509216

[4]*Mechanical Engineering Department, J.N.T. University, Hyderabad- 500 085.*

## ABSTRACT

*Investigations are carried out to evaluate the performance of variable speed, variable compression ratio, four- stroke, single cylinder, spark ignition (SI)engine having copper coated engine [CCE, copper-(thickness, 300 μ) coated on piston crown and inner side of cylinder head] provided with catalytic converter with sponge iron as catalyst with different test fuels of pure gasoline, gasohol (80% gasoline and 20% ethanol by volume) and methanol blended gasoline and compared with conventional engine (CE) with pure gasoline operation. Brake thermal efficiency increased with gasohol with both versions of theengine.*

*CCE showed improved performance when compared to CE with both test fuels. Brake thermal efficiency increased with compression ratio and marginally with speed of the engine. Methanol blended gasoline decreased pollutants effectively in comparison with gasohol with both versions of the engine. Catalytic converter with air injection significantly reduced pollutants with different test fuels on both configurations of theengine.*

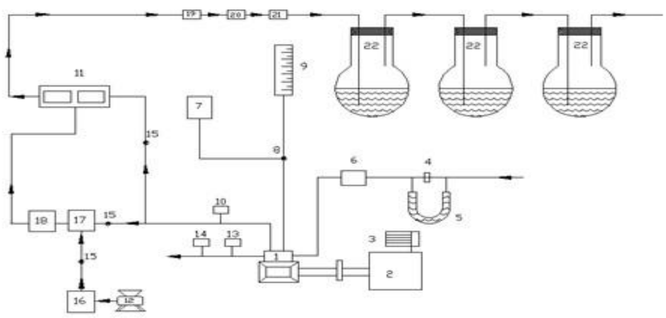
***Keywords:*** *SI engine, CCE, Performance, Pollutants, Catalytic converter, Air injection*

## INTRODUCTION

The civilization of a particular country depends on number of automotive vehicles being used by the public of the country. Common man is forced, these days to travel long distances even for his/her routine works as the tremendous rate at which population explosion is taking place imposes expansion of the cities to larger areas, which causes an increase in vehicle population at an alarm rate thus bringing in pressure in Government to spend huge foreign currency for importing crude petroleum to meet the fuel needs of the automotive vehicles. The large amount of pollutants emitting out from the exhaust of the automotive vehicles run on fossil fuels is also increasing as this is proportional to number of vehicles. In view of heavy consumption of gasoline fuel due to individual transport and also fast depletion of fossil fuels, the search for alternate fuels has become pertinent apart from effective fuel utilization which has been the concern of the engine manufacturers, users and researchers involved in combustion & alternate fuel research. SI engine has many advantagesover compression ignition (CI) engine and some of them are superior weight to power ratio, less vibrations, more comfort etc,. Alcohols are probable candidates as alternate fuels for SI engines, as their properties are compatible close to gasoline fuels. That too their octane rating is very high. If alcohols are blended in small quantities with gasoline fuels, no engine modification is necessary.

Carbon monoxide (CO) and un-burnt hydrocarbons (UBHC), major exhaust pollutants formed due to incomplete combustion of fuel, cause many human health disorders [1-6]. Such pollutants also cause detrimental effects [6] on animal and plant life, besides environmental disorders. If the engine is run with alcohol, aldehydes are also to be checked. These aldehydes are carcinogenic in nature. The amount of pollutants from the engine depends [3] on driving engine condition, driving methodology, road layout, traffic density, etc,. Hence control of these pollutants is immediate task. There are many methods to improve the performance of the engine out of which engine modification [7-8] with copper coating on piston crown and inner side of cylinder head improves engine performance as copper is a good conductor of heat and combustion is improved with copper coating. Out of many methods available to control pollutants from the engine, catalytic converter is effective [9-10] in reduction of pollutants in SI engine. Engine performance is improved [11-16] with change in fuel composition also. It is further improved [17-20] with simultaneous change of fuel composition and engine modification. Alcohols are blended with gasoline and used in copper coated engine so as to improve the performance of the engine. However, no systematic investigations are reported with the use of alcohols in copper coated engine with varied engine parameters. The present paper reports the performance evaluation of CCE, with different test fuels of pure gasoline, gasohol and methanol blended gasoline (20% by volume) with varied speed, compression ratio and compared with CE with pure gasoline operation. The pollutants of carbon monoxide (CO), un-burnt hydro carbons (UBHC) and aldehydes are controlled by catalytic converter with sponge iron as catalyst.

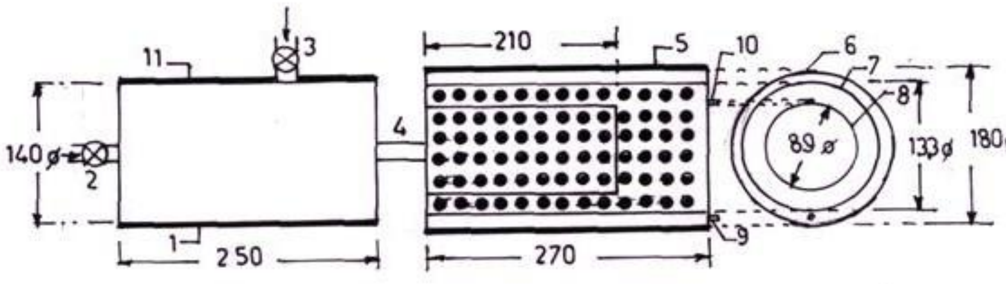
## EXPERIMENTAL PROGRAMME



1. Engine, 2.Eddy current dynamometer, 3. Loading arrangement, 4. Orifice meter, 5. U-tube water monometer, 6. Air box, 7. Fuel tank, 8. Three-way valve, 9. Burette,10. Exhaust gas temperature indicator, 11. CO analyzer, 12. Air compressor, 13. Outlet jacket water temperature indicator, 14. Outlet jacket water flow meter,15. Directional valve, 16. Rotometer, 17. Air chamber and 18. Catalyst chamber 19. Filter, 20. Rotometer, 21. Heater, 22. Round bottom flasks containing DNPH solution

**Fig.1 Experimental set up**

Fig.1 shows experimental set-up used for investigations. A four- stroke, single-cylinder, water-cooled, SI engine (brake power 2.2 kW, rated speed 3000 rpm) is coupled to an eddy current dynamometer for measuring brake power. Compression ratio of engine is varied (3 - 9) with change of clearance volume by adjustment of cylinder head, threaded to cylinder of the engine. Engine speeds are varied from 2000 to 3000 rpm. Exhaust gas temperature is measured with iron- constantan thermocouples. Fuel consumption of engine is measured with burette method, while air consumption is measured with air-box method. In catalytic coated engine, piston crown and inner surface of cylinder head are coated with copper by plasma spraying. A bond coating of Ni-Co-Cr alloy is applied (thickness, 100 μ) using a 80 kW METCO plasma spray gun. Over bond coating, copper (89.5%), aluminium (9.5%) and iron (1.0%) are coated (thickness 300 μ). The coating has very high bond strength and does not wear off even after 50 h of operation [7]. Performance parameters of brake thermal efficiency (BTE), exhaust gas temperature (EGT) and volumetric efficiency (VE) are evaluated at different magnitudes of brake mean effective pressure (BMEP) of the engine. CO and UBHC emissions in engine exhaust are measured with Netel Chromatograph analyzer. DNPH method [8] is employed for measuring aldehydes in the experimentation. The exhaust of the engine is bubbled through 2,4 dinitrophenyl hydrazine (2,4 DNPH) solution. The hydrazones formed are extracted into chloroform and are analyzed by employing high performance liquid chromatography (HPLC) to find the percentage concentration of formaldehyde and acetaldehyde in the exhaust of theengine.




Note: All dimensions are in mm.

1.Air chamber, 2.Inlet for air chamber from the engine, 3.Inlet for air chamber from compressor, 4.Outlet for air chamber, 5.Catalyst chamber, 6. Outer cylinder, 7. Intermediate cylinder, 8.Inner cylinder, 9. Outlet for exhaust gases, 10.Provision to deposit the catalyst and 11.Insulation

**Fig.2. Details of Catalytic converter**

A catalytic converter [9] (Fig.2) is fitted to exhaust pipe of engine. Provision is also made to inject a definite quantity of air into catalytic converter. Air quantity drawn from compressor and injected into converter is kept constant so that backpressure does not increase. Experiments are carried out on CE and CCE with different test fuels under different operating conditions of catalytic converter like set-A, without catalytic converter and without air injection; set-B, with catalytic converter and without air injection; and set-C, with catalytic converter and with air injection.

## RESULTS AND DISCUSSION

This chapter is divided into three parts, i) performance parameters, ii) pollution levels and iii) catalytic converter.

### Performance Parameters

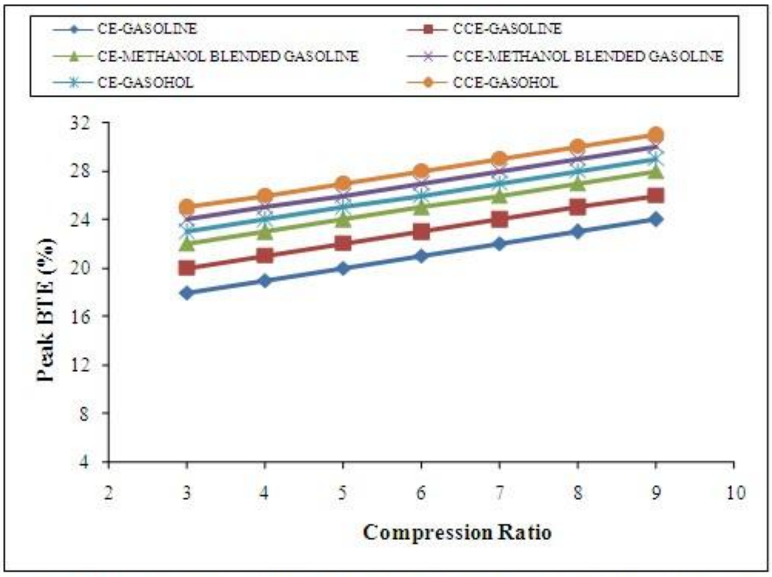



**Fig.3 Variation of peak BTE with compression ratio in both versions of the engine with test fuels at a speed of 3000 rpm.**

Fig. 3 shows variation of peak BTE with compression ratio with test fuels at a speed of 3000 rpm. As compression ratio increases peak BTE increases in both versions of the engine with test fuels. This is due to increase of expansion work. Gasses are expanded from higher value giving rise to work on the piston. At a compression ratio of 9:1 it is observed higher peak BTE with test fuels in both versions of theengine.

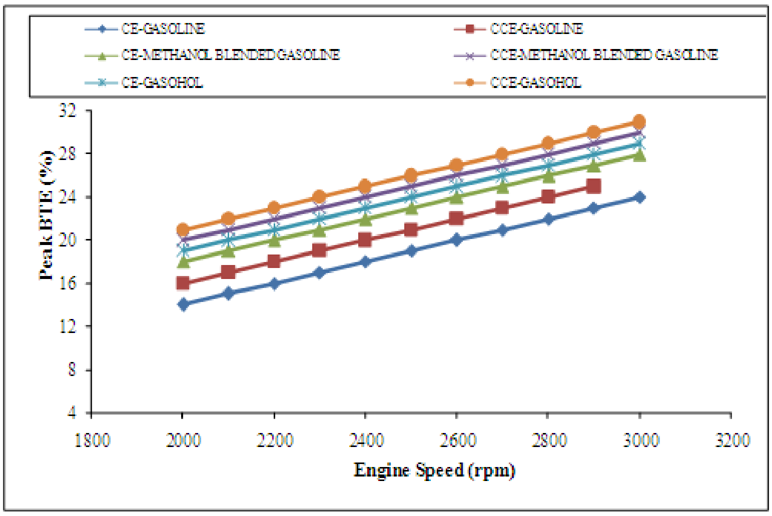



**Fig.4 Variation of peak BTE with speed of the engine in both versions of the engine with test fuels at a compression ratio of 9:1.**

Fig. 4 shows variation of peak BTE with speed of the engine with test fuels at a compression ratio of 9:1. Peak BTE increases with an increase of speed of the engine. This is due to increase of turbulence of combustion. Catalytic activity is pronounced at higher speeds leading to produce higher BTE. At a engine speed of 3000 rpm, it is observed higher peak BTE with test fuels in both versions of the engine.

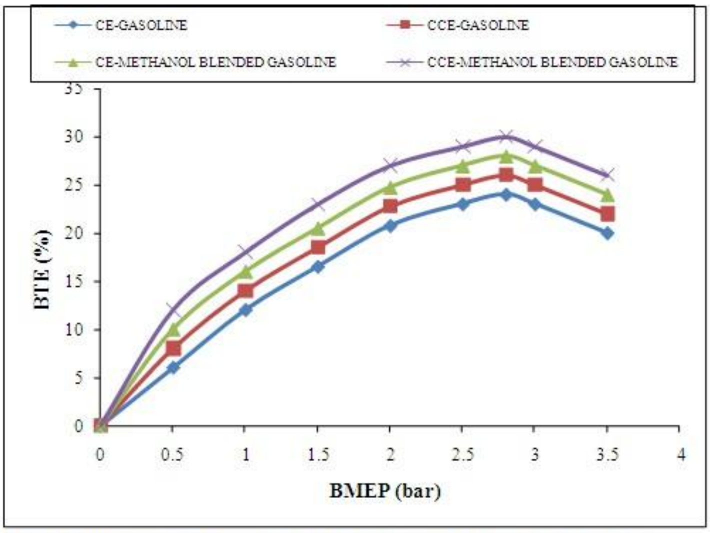



**Fig.5 Variation of BTE with BMEP of the engine in both versions of the engine with pure gasoline and methanol blended gasoline at a speed of 3000 rpm and compression ratio of 9;1.**

Fig.5.shows the variation of BTE with BMEP in different versions of the engine with pure gasoline and methanol blended gasoline at a compression ratio of 9:1 and speed of 3000 rpm, which indicated that BTE increased with an increase of BMEP. Higher BTE is observed with methanol blended gasoline over pure gasoline at all loads due to lower Stoichiometric air requirement of methanol blended gasoline over pure gasoline operation. CCE showed higher thermal efficiency when compared to CE with both test fuels at loads, particularly at near full load operation, due to efficient combustion with catalytic activity, which is more pronounced at peak load, as catalytic activity increases with prevailing high temperatures at peak load. Peak BTE increased with increase of compression ratio with CE and CCE at different test fuels, due to increase in expansion work with increase of compression ratio.

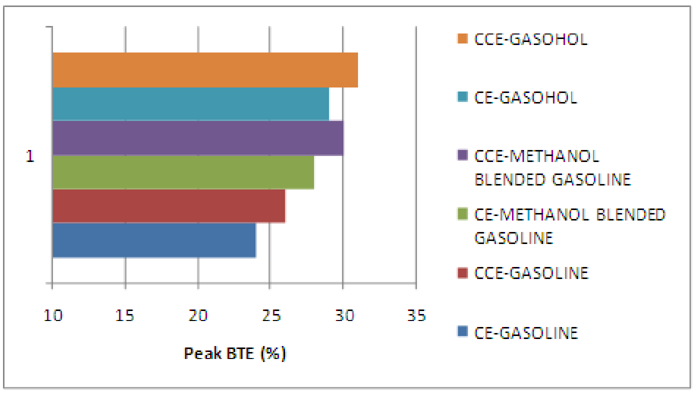



**Fig.6 Bar charts showing the variation of peak BTE in both versions of the engine with test fuels at a speed of 3000 rpm and compression ratio of 9;1.**

Fig. 6 presents the bar chart, which shows the variation of peak BTE in both versions of the engine with test fuels at a speed of 3000 rpm and a compression ratio of 9:1. CCE with gasohol gave higher peak BTE when compared with methanol blended gasoline in both versions of the engine. This is due to higher calorific value of ethanol in comparison with methanol giving rise to more energy supplied which is a product of fuel burning rate and calorific value.

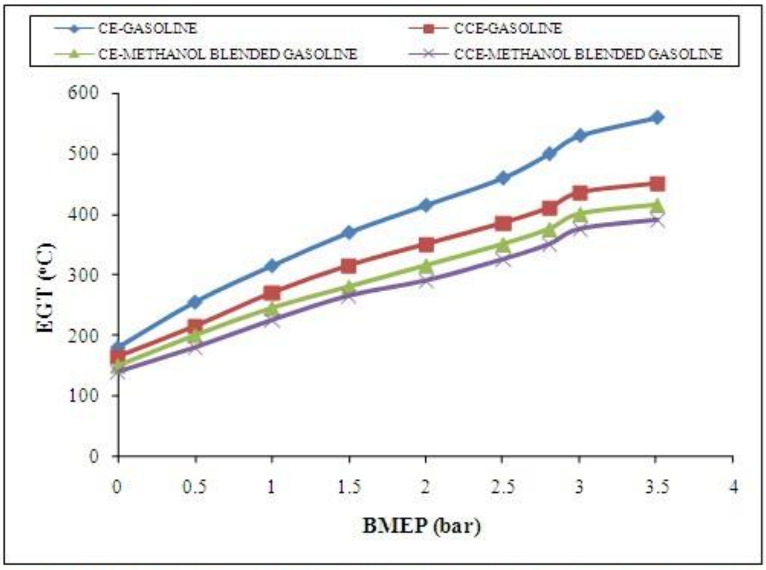



**Fig.7 Variation of EGT with BMEP of the engine in both versions of the engine with pure gasoline and methanol blended gasoline at a speed of 3000 rpm and compression ratio of 9;1.**

Fig.7. shows the variation of EGT with BMEP in different versions of the engine with pure gasoline and methanol blended gasoline at a compression ratio of 9:1 and speed of 3000 rpm, which indicated that EGT increased with an increase of BMEP. EGT value is observed to be less with methanol blended gasoline in comparison with pure gasoline in both versions of the engine. This is due to higher value of latent heat of evaporation of methanol which absorbs heat from combustion. Pure gasoline operation on CE recorded higher value of EGT, while methanol blended gasoline operation on CCE gave lower value of EGT, as with methanol blended gasoline, work transfer from piston to gases in cylinder at the end of compression stroke is too large, leading to reduction in the magnitude of EGT.

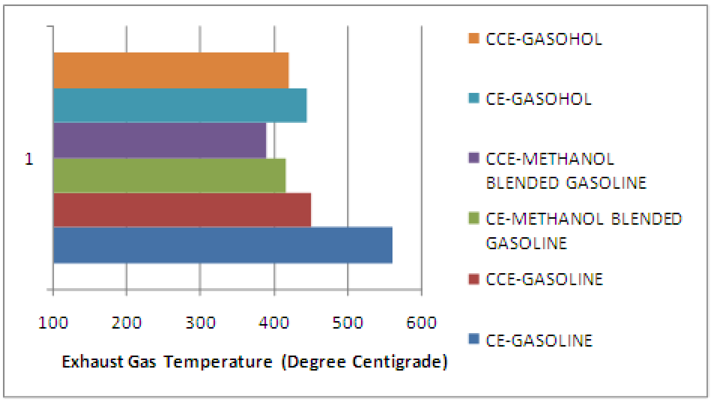



**Fig.8 Bar charts showing the variation of EGT at peak load operation in both versions of the engine with test fuels at a speed of 3000 rpm and compression ratio of 9;1.**

Fig. 8 presents bar chart, which shows the variation of EGT at peak load operation in both versions of the engine with test fuels. EGT is observed to be less with methanol blended gasoline in comparison with gasohol in both versions of the engine. This is due to higher value of latent heat of evaporation of methanol.

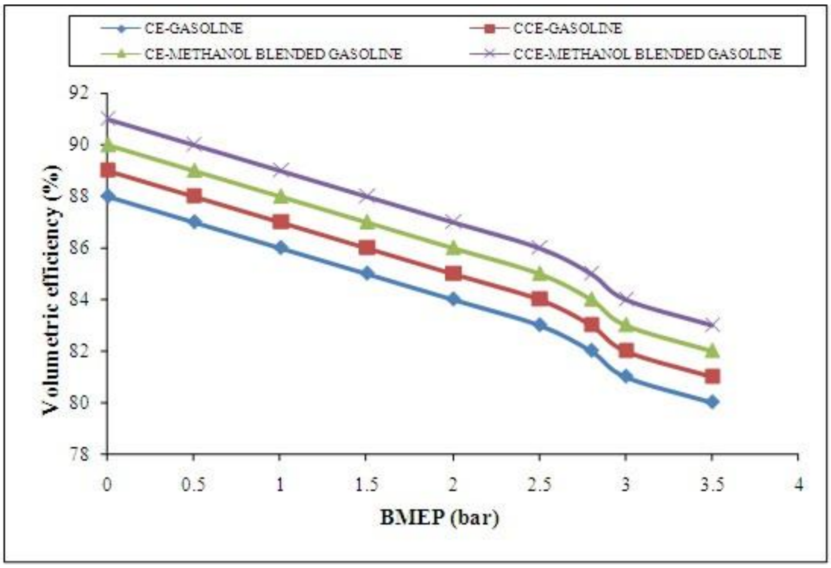



**Fig.9 Variation of VE with BMEP of the engine in both versions of the engine with pure gasoline and methanol blended gasoline at a speed of 3000 rpm and compression ratio of 9;1.**

Fig. 9 shows the variation of volumetric efficiency (VE) with BMEP in different versions of the engine with methanol blended gasoline and pure gasoline at a compression ratio of 9;1 and at a speed of 3000 rpm. VE decreased with an increase of BMEP with test fuels in both versions of the engine. This is due to increase of gas temperatures with increase of BMEP. Methanol blended gasoline showed higher VE in comparison with gasoline operation in both configuration of the engine due to increase of mass and density of air with reduction of the temperature of air due to high latent heat of evaporation of methanol. CCE showed higher VE at all loads in comparison with CE with different test fuels, due to reduction ofresidual charge and deposits in the combustion chamber of CCE when compared to CE, which shows the same trend as reported earlier [7] .

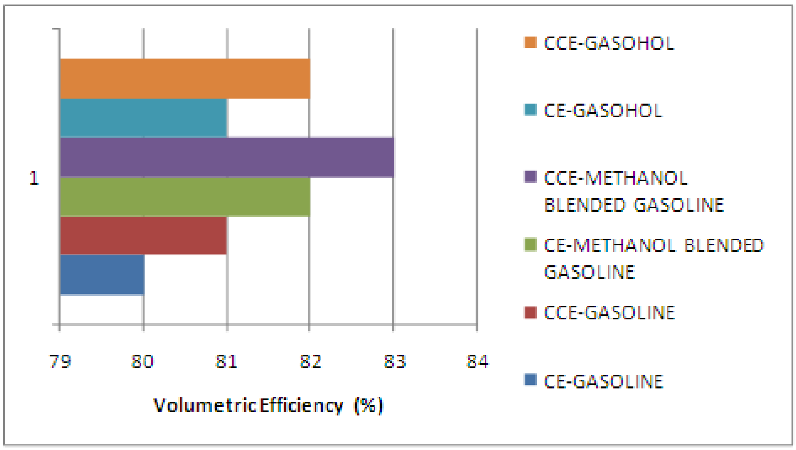



**Fig.10 Bar charts showing the variation of Volumetric efficiency at peak load operation in both versions of the engine with test fuels at a speed of 3000 rpm and compression ratio of 9;1.**

Fig. 10 presents the bar chart, which shows the variation of VE at peak load operation with test fuels in both versions of the engine. Methanol blended gasoline in CCE showed marginally higher VE in comparison with gasohol in the same configuration of the engine. This is due to as mentioned earlier higher value of latent heat of evaporation.

**Pollution Levels**

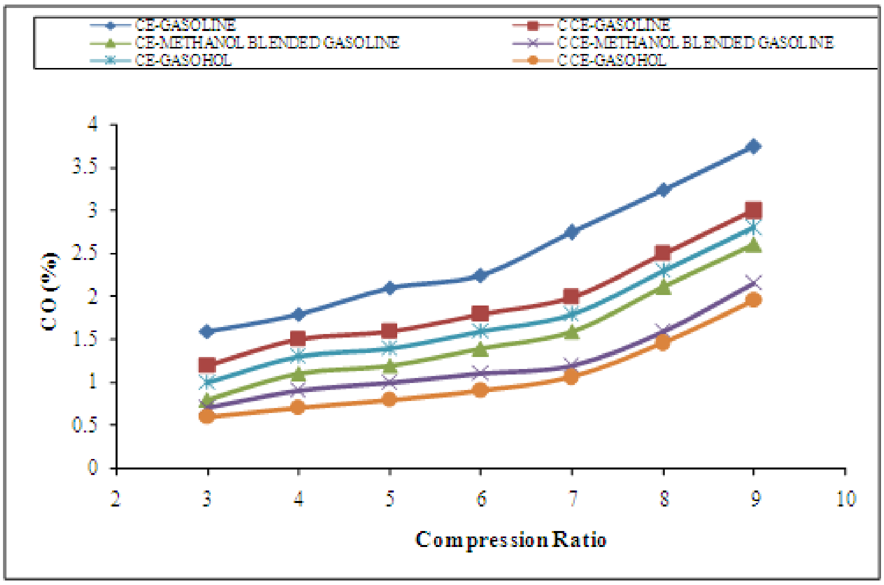



**Fig. 11. Variation of CO emissions with compression ratio in both versions of the engine at a speed of 3000 rpm with test fuels.**

Fig. 11 shows the variation of CO emissions in both versions of the engine with compression ratio with test fuels at a speed of 3000 rpm. As compression ratio decreases, CO emissions decreases in both versions of the engine with test fuels. This is due to increase of exhaust gas temperatures with decrease of compression ratios leading to oxidation of CO emissions in the exhaust pipe producing CO2 emissions. Similar trends were reported [18] earlier.

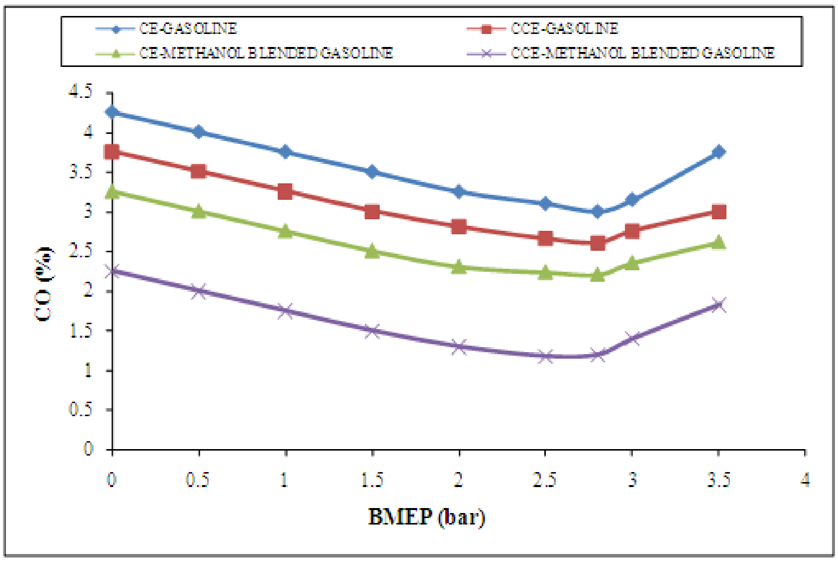



**Fig.12 Variation of CO emissions with BMEP of the engine in both versions of the engine with pure gasoline and methanol blended gasoline at a speed of 3000 rpm and compression ratio of 9;1.**

Fig. 12 shows the variation of CO emissions with BMEP in different versions of the engine wit both test fuels. Methanol blended gasoline decreased CO emissions at all loads when compared to pure gasoline operation on CCE and CE, as fuel-cracking reactions are eliminated with methanol. The combustion of alcohol produces more water vapor than free carbon atoms as methanol has lower C/H ratio of 0.25 against 0.44 of gasoline. Methanol has oxygen in its structure and hence its blends have lower stoichiometric air requirements compared to gasoline. Therefore more oxygen that is available for combustion with the blends of methanol and gasoline, leads to reduction of CO emissions. Methanol dissociates in the combustion chamber of the engine forming hydrogen, which helps the fuel-air mixture to burn quickly and thus increases combustion velocity, which brings about complete combustion of carbon present in the fuel to CO2 and also CO to CO2 thus makes leaner mixture more combustible, causing reduction of CO emissions. CCE reduces CO emissions in comparison with CE. Copper or its alloys acts as catalyst in combustion chamber, whereby facilitates effective combustion of fuel leading to formation of CO2 instead of CO. Similar trends are observed with Reference-10 with pure gasoline operation onCCE.

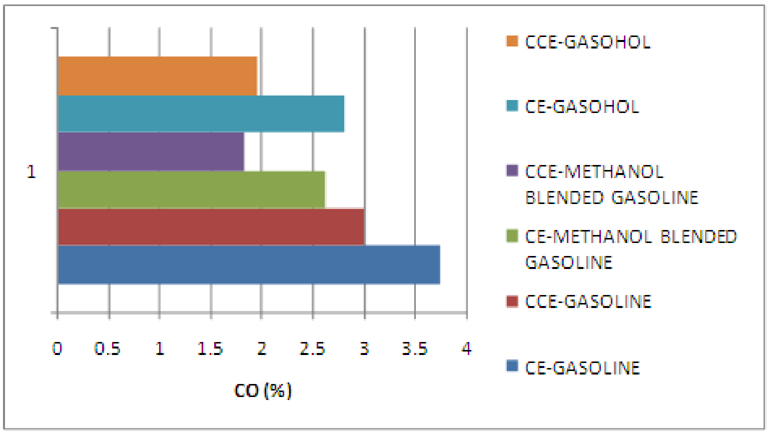



**Fig.13** Bar charts showing the variation of CO emissions at peak load operation in both versions of the engine with test fuels at a speed of 3000 rpm and compression ratio of 9;1.

Fig. 13 presents the bar chart, which shows the variation of CO emissions at peak load operation with test fuels in both versions of the engine. CO emissions are observed to be marginally less with methanol blended gasoline in comparison with gasohol at peak load operation on both versions of the engine. This is due to lower value of C/H ratio of methanol in comparison with ethanol.

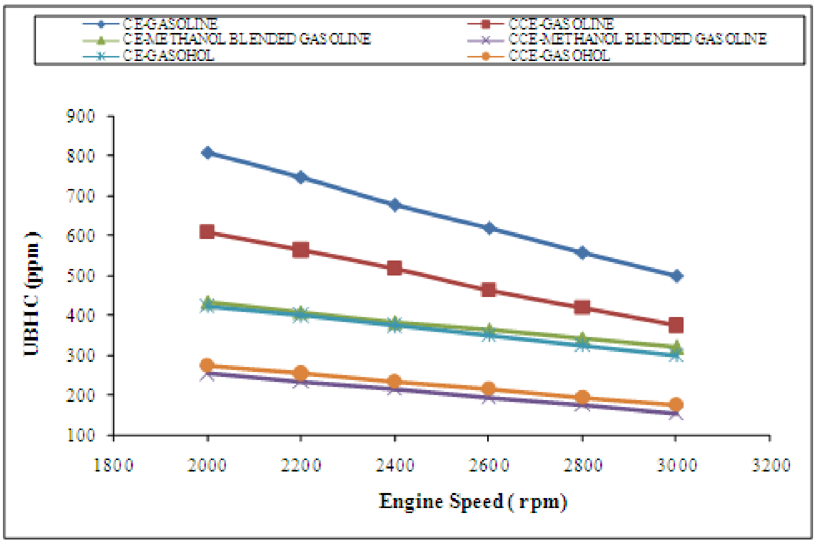



**Fig. 14** Variation of UBHC emissions with speed of the engine in both versions of the engine with test fuels at a speed of 3000 rpm and compression ratio of 9;1.

Fig. 14 shows the variation of UBHC emissions with speed of the engine in both versions of the engine with test fuels at a compression ratio of 9:1. As speed increases, UBHC emissions decreases in both versions of the engine with test fuels. This is due to increase of turbulence causing efficient combustion leading to decrease UBHC emissions.

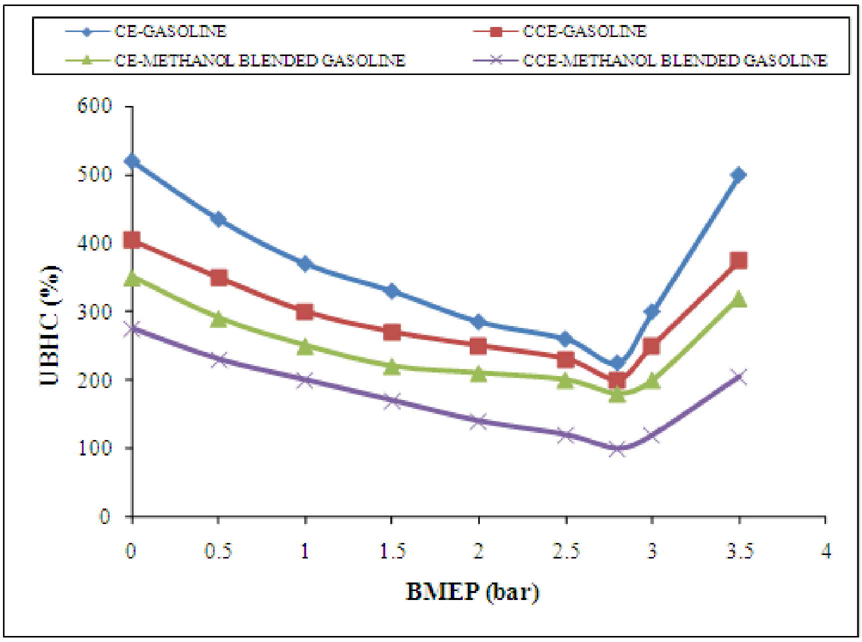



**Fig.15 Variation of UBHC emissions with BMEP of the engine in both versions of the engine with pure gasoline and methanol blended gasoline at a speed of 3000 rpm and compression ratio of 9;1.**

Fig.15 shows the variation of un-burnt hydro carbon emissions (UBHC) with BMEP in different versions of the engine with both test fuels. UBHC emissions followed the same trend as CO emissions in CCE and CE with both test fuels, due to increase of flame speed with catalytic activity and reduction of quenching effect with CCE. Catalytic converter reduced pollutants considerably with CE and CCE and air injection into catalytic converter further reduced pollutants. In presence of catalyst, pollutants get further oxidised to give less harmful emissions likeCO2.

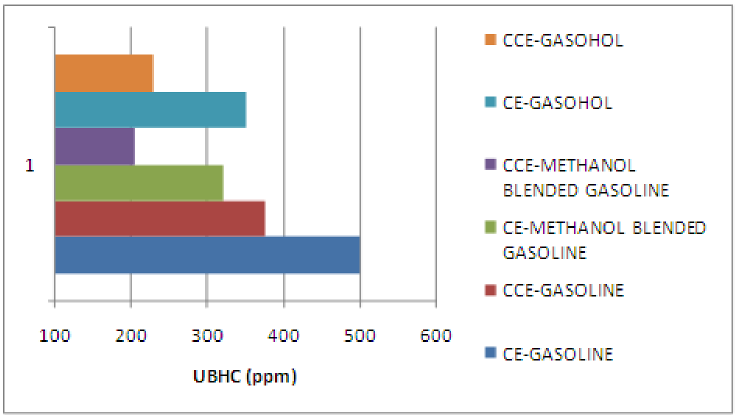



**Fig.16 Bar charts showing the variation of UBHC emissions with BMEP of the engine in both versions of the engine with test fuels at a speed of 3000 rpm and compression ratio of 9;1.**

Fig. 16 presents the bar charts, which shows the variation of UBHC emissions at peak load operation with test fuels in both versions of the engine. UBHC emissions are observed to be less with methanol blended gasoline in comparison with gasohol at peak load operation on both versions of the engine. This is due to efficient combustion with methanol blended gasoline causing no accumulation of fuel in crevices of piston and combustion chamber walls.

**Catalytic Converter**

**TABLE-1**

**Data of Pollution Levels in four-stroke SI engine with different test fuels at different operating conditions of catalytic converter**

| Pollutant | Set | Pure Gasoline Operation | | Gasohol Operation | | Methanol blended gasoline | |
|---|---|---|---|---|---|---|---|
| | | CE | CCE | CE | CCE | CE | CCE |
| CO (%) | Set-A | 3.75 | 3.0 | 2.81 | 1.96 | 2.61 | 1.83 |
| | Set-B | 2.25 | 1.8 | 1.54 | 1.4 | 1.52 | 1.1 |
| | Set-C | 1.5 | 1.2 | 0.98 | 0.78 | 0.81 | 0.58 |
| | | | | | | | |
| UBHC (ppm) | Set-A | 500 | 375 | 350 | 228 | 320 | 205 |
| | Set-B | 300 | 206 | 165 | 130 | 135 | 105 |
| | Set-C | 200 | 105 | 122 | 80 | 90 | 65 |
| | | | | | | | |
| Formaldehyde (% Concentration) | Set-A | 6.5 | 4.5 | 12 | 9.0 | 10.5 | 9.0 |
| | Set-B | 4.5 | 2.5 | 5.6 | 5.1 | 7.35 | 3.4 |
| | Set-C | 2.5 | 1.5 | 4.8 | 3.4 | 4.2 | 2.3 |
| | | | | | | | |
| Acetaldehyde (% Concentration) | Set-A | 5.5 | 3.5 | 10.45 | 6.6 | 14.3 | 9.1 |
| | Set-B | 3.5 | 2.5 | 4.7 | 3.4 | 9,3 | 5.9 |
| | Set-C | 1.5 | 1.0 | 3.7 | 2.3 | 4.0 | 2.5 |

Table-1 shows the data of pollution levels which includes CO emissions, UBHC emissions, Formaldehyde emissions and Acetaldehyde emissions at peak load operation with test fuels with different configurations of the engine at different operating conditions of the catalytic converter. From the Table-1, it can be noticed that CO emissions decreased considerably with Set-B operation, while Set-C further decreased emissions in both versions of the engine with test fuels. Efficient combustion with alcohol blended gasoline coupled with catalytic activity decreased CO emissions in CCE. From the same Table, it can be noticed that UBHC emissions decreased considerably with Set-B operation, while Set-C further decreased emissions in both versions of the engine with test fuels. Improved combustion with alcohol blended gasoline along with turbulence with catalytic activity decreased deposits in CCE causing decrease of UBHC emissions. From the Table, it can be noticed that formaldehyde emissions decreased considerably with Set-B operation, while Set-C further decreased emissions in both versions of the engine with test fuels. However, alcohol blended gasoline increased aldehyde emissions considerably in comparison with pure gasoline operation. But CCE decreased aldehyde emissions in comparison with CE with alcohol blended gasoline. This is due to improved combustion so that intermediate compounds will not be formed. Gasohol increased acetaldehyde emissions and methanol blended gasoline increased formaldehyde emissions. This is due to the nature of the fuel.

## CONCLUSIONS

Peak BTE is improved with gasohol operation while pollution levels decreased with methanol blended gasoline. CCE improved combustion and decreased pollutants effectively in comparison with CE with test fuels. Set-B operation of the catalytic converter decreased the pollutants by 40%, while Set- C by 60%.

## REFERENCES

1. M.H.Fulekar, Chemical pollution – a threat to human life, Indian J Env Prot, 1, (1999) 353-359.

2. T.Usha Madhuri T.Srinivas & K.Ramakrishna, A study on automobile exhaust pollution with regard to carbon monoxide emissions, Nature, Environ & Poll Tech, 2 (2003)473-474.

3. S.M. Khopkar Environmental Pollution Analysis, edited by [New AgeInternational (P) Ltd, Publishers, New Delhi] (2004) 180-190.

4. M.S.Sastry, M.Suneela, N.P.S.Kumar and S.K.Hussain, Air quality status at selected locations in Hyderabad city, J Environ Sci &Engg, 46,(2004)86-91.

5. M.K.Ghose, R.Paul and S.K.Benerjee, Assessment of the impact of vehicle pollution on urban air quality, J Environ Sci &Engg , 46, (2004)33-40.

6. B.K. Sharma Engineering Chemistry, edited by [Pragathi Prakashan (P) Ltd, Meerut] (2005)150-160.

7. N.Nedunchezhian & S.Dhandapani Experimental investigation of cyclic variation of combustion parameters in a catalytically activated two-stroke SI engine combustion chamber, Engg Today, 2 (2000)11-18.

8. P.V.K.Murthy, M.V.S.Murali Krishna, S.Narasimha Kumar, K.Kishor and P.Giridhar Reddy, Performance of copper coated two stroke spark ignition engine with alternate fuels with catalytic converter, International Journal of Engineering & Techno-science, 2(2), (2011)145-149.

9. M.V.S.Murali Krishna C.M.Vara Prasad and Ch.Venkata Ramana Reddy, Studies on control of carbon monoxide emissions in spark ignition engine using catalytic converter, Ecol Env & Conser, 6 (2000)377-380.

*10.* M.V.S.Murali Krishna, K.Kishor, P.R.K.Prasad and G.V.V.Swathy, Parametric studies of pollutants from copper coated spark ignition engine with catalytic converter with gasoline blended methanol, Journal of Current Sciences, 9 (2), (2006)529-534.

11. A.A.Al-Farayedhi, A.M.Al-Dawood and P.Gandhidasan, Experimental investigation of spark ignition engine performance using oxygenated fuel, ASME Journal of Engineering for Gas Turbines and Power, Volume- 126, (2004)178-191.

12. O.Abu-Zaid., Badran and J.Yamin, Effect of methanol addition on the performance of spark ignition engines, Energy & Fuels, Volume-18, (2004) 312-315.
13. K.Nakata, The effect of ethanol fuel on a spark ignition engine, SAE Paper No.2006-01-3380,(2006).

14. R.J.Pearson, Alcohol based fuels in high performance engines, SAE Paper No - 2007-01-0056,(2007).

15. M.Bahattin Celik, Experimental determination of suitable ethanol–gasoline blend rate at high compression ratio for gasoline engine, Applied Thermal Engineering, Volume-28, (2008)396–404.

16. C.Rodrigo Costa. and R.José. Sodré., Hydrous ethanol vs. gasoline-ethanol blend: engine performance and emissions, Fuel 89, (2010)287–293.

17. M.V.S.Murali Krishna and K.Kishor, Investigations on catalytic coated spark ignition engine with methanol blended gasoline with catalytic converter, Indian Journal (CSIR) of Scientific and Industrial Research, Volume-67, (2008)543-548.

*18.* M.V.S.Murali Krishna, K.Kishor, P.V.K.Murthy, A.V.S.S.K.S.Gupta and S.Narasimha Kumar, Performance evaluation of copper coated four stroke spark ignition engine with gasohol with catalytic converter, *International Journal of* Engineering Studies, 2(4), (2010)465-473.

*19.* P.V.K.Murthy, M.V.S.Murali Krishna S.Narasimha Kumar, K.Kishor and P.Giridhar Reddy, Performance of copper coated two stroke spark ignition engine with alternate fuels with catalytic converter, International Journal of Engineering & Techno-science, 2(2), (2011)145-149.

20. S.Narasimha Kumar, M.V.S.Murali Krishna, P.V.K. Murthy, V.V.R. Seshagiri Rao, and D.N.Reddy, D.N., Performance of copper coated two stroke spark ignition engine with gasohol with catalytic converter, International Journal on Mechanical & Automobile Engineering (IJMAE),12(1), (2011)36-43