International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Experimental Investigations on Performance Parameters with Four Stroke Spark Ignition Engine with Copper Coated Combustion Chamber with Gasohol

Y. Nagini†, Maddali V.S. Murali Krishna†* and S. Naga Sarada‡

†Mechanical Engineering Department, Chaitanya Bharathi Institute of Technology, Gandipet, Hyderabad- 500 075, Telangana State, India
‡Department of Mechanical Engineering, College of Engineering, JNT University, Hyderabad- 500 085, Telangana State, India

Accepted 15 May 2016, Available online 22 May 2016, **Vol.6, No.3 (June 2016)**

Abstract

The petrol engine has provided reliable small units for personalized transport and in this way revolutionized the living habits of people to a great extent. Indeed the petrol engine powered automobile and diesel engine powered buses and trucks are the symbols of our modern technological society. Four stroke engines offer many advantages like higher thermal efficiency, volumetric efficiency than two stroke engines. In the scenario of depletion of fossil fuels, the search for alternative fuels has become inevitable. Alcohols, the renewable fuels are important substitutes of gasoline, as their properties are comparable to gasoline fuels. That too, their octane numbers are greater than those of gasoline fuels. Experiments were conducted to evaluate the performance of the engine with a variable compression ratio (3-9), four–stroke, single–cylinder spark ignition (SI) engine with gasohol (20% ethanol, 80% gasoline, by vol) having copper coated engine [CCE, copper-(thickness,300 µ) coated on piston crown, inner side of liner and cylinder head] and compared with conventional SI engine (CE) with neat gasoline operation. Performance parameters of brake thermal efficiency, brake specific energy consumption, exhaust gas temperature and volumetric efficiency at full load operation were determined with CCE with gasohol and compared with CE with neat gasoline operation. CCE showed improved performance over CE with both test fuels.

***Keywords**: Alternative fuels, methanol, ethanol, CE, CCE, performance parameters*

Introduction

Throughout history, alcohols have been used as a fuel. The first four aliphatic alcohols (methanol, ethanol, propanol, and butanol) are of interest as fuels because they can be synthesized chemically or biologically, and they have characteristics which allow them to be used in internal combustion engines. The general chemical formula for alcohol fuel is $C_nH_{2n+1}OH$.

Most methanol is produced from natural gas, although it can be produced from biomass using very similar chemical processes. Ethanol is commonly produced from biological material through fermentation processes.

However, ethanol that is derived from petroleum should not be considered safe for consumption as the mixture contains about 5% methanol and may cause blindness or death. Bio butanol has the advantage in combustion engines in that its energy density is closer to gasoline than the simpler alcohols (while still retaining over 25% higher octane rating); however, bio butanol is currently more difficult to produce than ethanol or methanol. When obtained from biological materials and/or biological processes, they are known as bio alcohols (e.g."bio ethanol"). There is no chemical difference between biologically produced and chemically produced alcohols.

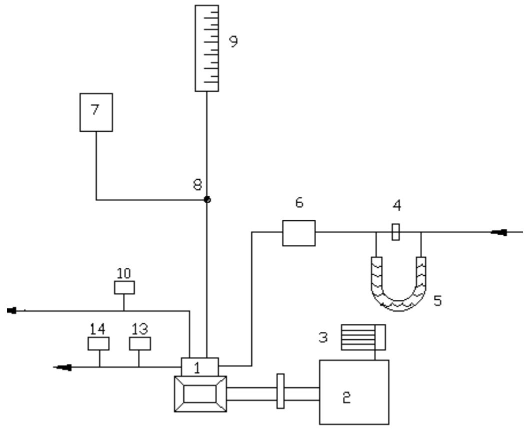
One advantage shared by the four major alcohol fuels is their high octane rating. This tends to increase their fuel efficiency and largely offsets the lower energy density of vehicular alcohol fuels (as compared to petrol/gasoline and diesel fuels), thus resulting in comparable "fuel economy" in terms of distance per volume metrics, such as kilometers per liter, or miles per gallon. Methanol is the simpler molecule, and ethanol can be made from methanol. Methanol can be produced industrially from nearly any biomass, including animal waste, or from carbon dioxide and water or steam by first converting the biomass to synthesis gas in a gasifier. It can also be produced in a laboratory using electrolysis or enzymes. [Heywood, 1988].In the context of depletion of fossil fuels due to increase of fuel consumption, the search for alternate and renewable fuels has also become pertinent. Alcohols are found to be the better alternate fuels for spark ignition engine, as the properties of alcohols are

*Corresponding author: **Maddali V.S. Murali Krishna**

very close to those of gasoline [Heywood, 1988]. In addition, no major modification in the engine is required if low quantities of ethanol/methanol are blended with gasoline in spark ignition engine. Many researchers conducted experiments with blends of alcohol with gasoline in conventional SI engine. [Al-Farayedhi *et al*, 2004; Abu Ziad *et al*, 2004; Ceviz *et al,* 2005; Nakata, 2006; Pearson, 2007; Bahattin *et al*, 2008]. They reported that performance improved with alcohol operation over gasoline operation. Methanol blended gasoline [gasoline blended with methanol, 20%, by vol) improved engine performance and decreased pollution levels when compared with neat gasoline on CE [Murali Krishna *et al,* 2008; Murali Krishna *et al,* 2011; Indira Priyadarsini *et al ,* 2013]. Gasoline blended with ethanol (20% by volume) improved performance of the copper coated engine when compared with gasoline operation on conventional engine [Murali Krishna *et al*, 2010]. Engine modification with copper coating on piston crown and inner side of cylinder head improves engine performance as copper is better conductor of heat and good combustion was achieved with copper coating. [Dandapani *et al,* 1991; *Nedunchezhian et al, 2000].*

2. Materials and Methods

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 2400 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 [Dandapani *et al,* 1991]. 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 [Dandapani *et al,* 1991]. Throttle valve of carburetor was adjusted to induct different mass flow rate of fuel in order to get different equivalence ratios.



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. NOx Analyzer along with catalytic converter, 11 CO analyzer, 12. Air compressor, 13. Outlet jacket water temperature indicator, 14. Outlet jacket water flow meter

Fig.1 Experimental Set Up

2.1 Manufacturing of ethanol [Hewood, 1988]

Ethanol is produced from organic materials such as grains, fruit, wood and even municipal solid wastes and waste or specifically grown biomass. The municipal solid wastes can be converted to alcohol. The wastes are first shredded and then passed under a magnet to remove ferrous materials. The iron free wastes are then gasified with oxygen. The product synthesis gas is cleaned by water scrubbing and other means to remove any particulates, entrained oils, H_2 S and CO_2. CO-shift conversion for H_2 / CO / CO_2 ratio adjustment, alcohol synthesis, and alcohol purification are accomplished. Ethanol is renewable in nature. They have oxygen in their molecular composition. They have low C/H value. It has a low stochiometric air fuel ratio. Its properties are suitable as blended fuel in spark ignition engine. Ethanol is renewable in nature. They have oxygen in their molecular composition. They have low C/H value. It has a low stochiometric air fuel ratio. Its properties are suitable as blended fuel in spark ignition engine. The properties of test fuels are shown in Table.1. [Nagini *et al*, 2014]. However, the excess vapor pressure as noticed from Table.1 with alcohol blends can lead to vapor problems (drivability problems), difficulties with hot starts, stalling, hesitation, and poor acceleration. It is possible to add high vapor pressure liquids or gases such as butane either generally or preferably during cold start situations. Either gasoline or LPG could be injected at cold starts to accomplish the same effect.

Table 1 Properties of Test Fuels [Nagini *et al*, 2014]

Property	Test Fuel		Test Method
	Gasoline	E-20	
Low Calorific Value (MJ/kg)	44.133	40.672	ASTM
Reid vapor pressure (kPa)	35.00	54.61	ASTM
Research Octane Number	84.8	93.4	ASTM
Density at 15.5ºC (kg/l)	0.7678	0.7782	ASTM
Latent Heat of Evaporation	600	650	

2.2 Operating conditions

Test fuels used in the experimentation were neat gasoline, gasohol (ethanol 20% by volume blended with gasoline). Different combustion chambers used in the investigations were conventional engine combustion chamber and copper coated combustion chamber.

3. Results and Discussion

Fig. 2 presents bar charts showing the variation of peak BTE in different versions of the engine with neat gasoline and gasohol at a compression ratio of 9:1 and speed of 3000 rpm. Higher BTE was observed with gasohol over neat gasoline at all loads due to lower Stoichiometric air requirement of gasohol over neat 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 was 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. Peak BTE drastically decreased at lower compression ratios. Thermal efficiency marginally increased with increase of engine speed, due to increase of turbulence of combustion, though friction power increased with an increase of speed.

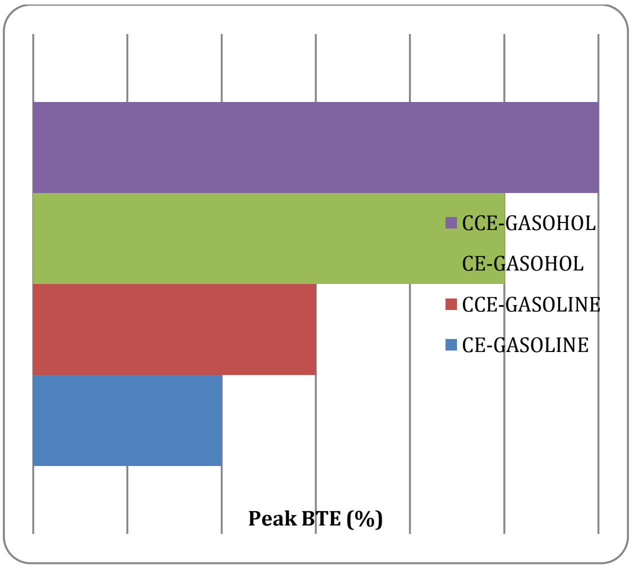


Fig.2 Bar charts showing the variation of peak BTE in different versions of the engine with test fuels at compression ratio of 9:1 and speed of 3000 rpm

Fig. 3 shows the variation of BTE with equivalence ratio, ϕ with both test fuels in both configurations of the engine. Efficiency was observed to be higher for both fuels at leaner mixture. When ϕ is equal to 0.9, gasoline fuel with both versions of the engine attains maximum value. It should be noted that it is necessary to use a lean mixture to eliminate fuel waste, while rich mixture is required to utilize all oxygen. Slightly leaner mixture would give maximum efficiency but too lean a mixture will burn slowly, increasing the time losses or will not burn at all causing total waste. In the rich mixture some of the fuel will not get oxygen and will be completely wasted. Also the flame speed in the rich mixture is low thereby increasing the time losses and lowering the efficiency. Lean mixture release less thermal energy resulting in lower flame temperature and flame speed. Very rich mixtures have incomplete combustion (Some carbon only burns to CO and not to CO_2, which results in production of less thermal energy and hence again flame speed is again low. Fuel air analysis suggests that thermal efficiency will deteriorate as the mixture supplied to the engine is enriched. That is explained by increasing losses due to variable specific heat and dissociation, is as the engine temperatures are raised by enrichment towards the chemically correct ratio. Enrichment beyond the chemically correct ratio results in the supply of unusable excess fuel and the thermal efficiency drops very rapidly. Thus the maximum efficiency is within the weak zone bear chemically correct ratio. As the mixture is made lean due to less energy input the temperature rise during the combustion will be less.

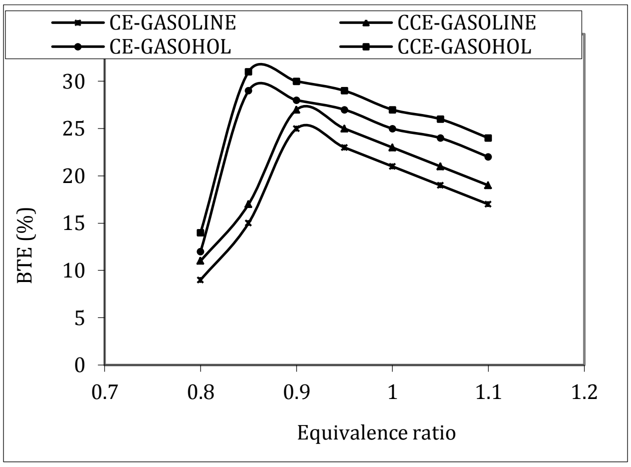


Fig.3 Variaton of BTE with Equivalene ratio in CE and CCE with both test fuels with a comression ratio of 9:1 and at a speed of 3000 rpm

The low temperature will result in lower specific heat. It will also mean lower chemical equilibrium losses (ie., larger fraction of fuel energy is in the form of sensible energy).The efficiency is therefore higher in fact approaches the air-cycle efficiency as the fuel ratio is reduced. As the mixture becomes richer the efficiency falls rapidly. This is because in addition to higher specific heats and chemical equilibrium losses there is insufficient air which will result in the formation of CO and H_2 in the combustibles, which represents the direct wastage of fuel. However, maximum efficiency is attained for methanol blended gasoline when ϕ =0.8 as stoichiometric air requirement of gasohol is less, compared to hydro carbon fuel. There was no effect of copper coating on the variation of BTE with equivalence ratio. However, copper coating improves the efficiency of the engine with both test fuels.

Fig.4 presents bar charts showing the variation of brake specific energy consumption (BSEC) at full load in different versions of the engine with both test fuels. Brake specific energy consumption defined as energy consumed by engine in producing unit brake power is important performance parameter to compare different test fuels on single engine. BSEC was observed to be lower with gasohol in comparison with neat gasoline operation. Lower stoichiometric ratio of methanol was one of the reasons to have lower BSEC. CCE gave lower BSEC than CE with both test fuels, which confirmed that combustion improved with catalytic activity in CCE.

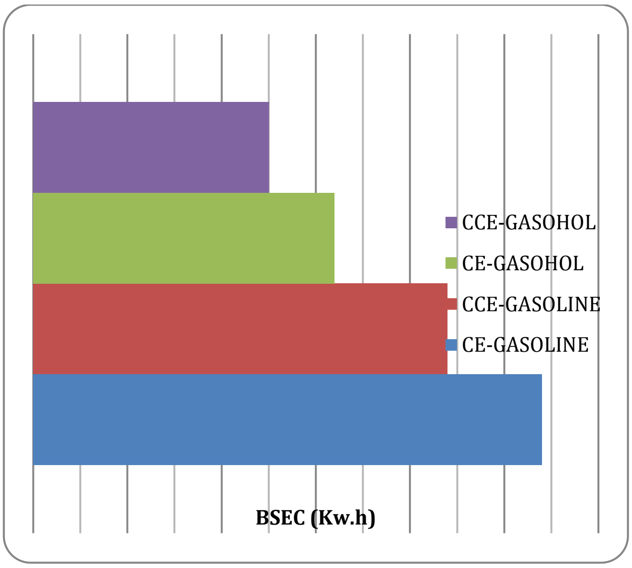


Fig.4 Bar charts showing the variation of brake specific energy consumption (BSEC) in different versions of the engine with test fuels at compression ratio of 9:1 and speed of 3000 rpm

Fig. 5 presents bar charts showing the variation of exhaust gas temperature (EGT) in different versions of the engine with both test fuels. EGT was lower with gasohol , when compared to neat gasoline at all loads in CE and CCE because, with gasohol, work transfer from piston to gases in cylinder at the end of compression stroke is too large, leading to reduction in EGT. High latent heat of evaporation of gasohol might have reduced EGT. CCE registered lower EGT when compared to CE for both test fuels, which confirmed efficient combustion with the CCE than CE. EGT decreased with increase of speed and compression ratio for CE and CCE with different test fuels. EGT is lower at higher compression ratio because increased expansion causes the gas to do more work on piston and less heat is rejected at the end of the stroke. Magnitude of EGT decreases marginally with increase of speed with different test fuels. Magnitude of EGT is high at lower compression ratios confirming that efficiency decreased with decrease of compression ratios.

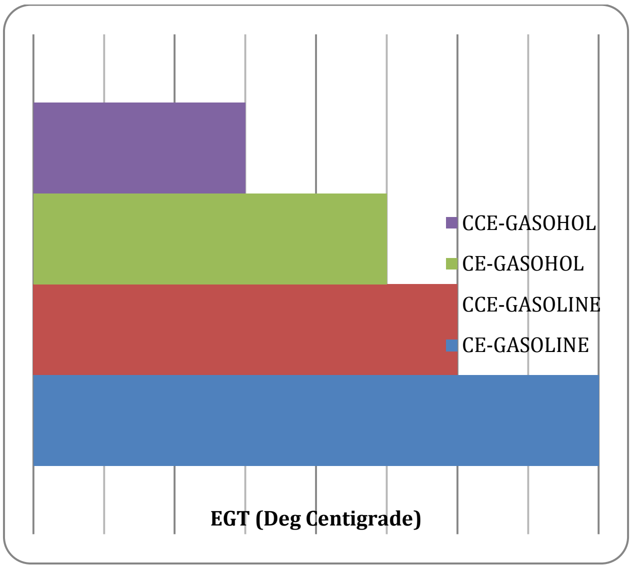


Fig.5 Bar charts showing the variation of exhaust gas temperature at full load in different versions of the engine with test fuels at compression ratio of 9:1 and speed of 3000 rpm

Fig.6 shows the variation of EGT with equivalence ratio ϕ in different versions of the engine with both test fuels

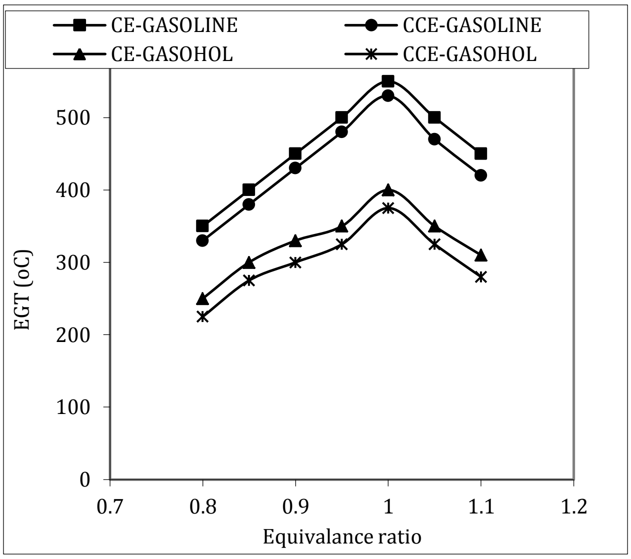


Fig.6 Variaton of exhaust gas temperatue with Equivalene ratio in CE and CCE with both test fuels with a comression ratio of 9:1 and at a speed of 3000 rpm.

EGT increases up to the value of ϕ =1 and later decreases for both test fuels with both configurations of the engine. The exhaust temperature was higher at the chemical correct mixture. At this point, the fuel and oxygen are completely used up as the effect of chemical equilibrium is not significant. At the lean mixtures because of less fuel, maximum temperature is less and hence exhaust gas temperature is less. At rich mixtures the formation of CO and UBHC emissions increases the fuel wastage and decreases the exhaust gas temperature.

Fig. 7 presents bar charts showing the variation of volumetric efficiency (VE) at full load in both configurations of the engine with both test fuels. CCE showed higher volumetric efficiency at all loads in comparison with CE with different test fuels, due to reduction of residual charge and deposits in the combustion chamber of CCE when compared to CE, which shows the same trend as reported earlier [Dandapani *et al,* 1991]. CCE with methanol blended gasoline showed volumetric efficiency 10% higher than that of CE at peak load operation of the engine with gasoline as fuel. Volumetric efficiency increased with gasohol when compared to pure gasoline operation with CE and CCE at all loads, due to increase of mass and density of air with reduction of temperature of air due to high latent heat of evaporation of methanol. Volumetric efficiency marginally increased with increase of engine speed with different test fuels with different versions of the engine, as volume of charge sucked into the cylinder is directly proportional to the engine speed. Volumetric efficiency marginally increased with increase of compression ratio of CE and CCE with different test fuels due to improvement in combustion with increase of compression ratio and reduction of deposits. However, VE decreased at lower speeds and lower compression ratios.

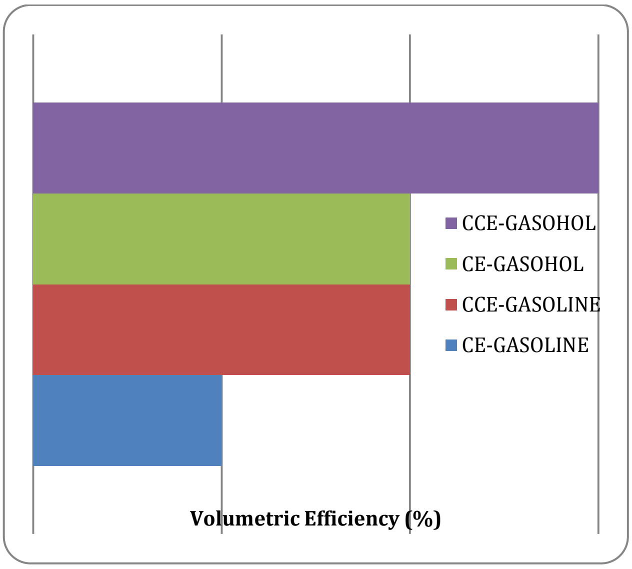


Fig.7 Bar charts showing the variation of volumetric efficiency at full load in different versions of the engine with test fuels at compression ratio of 9:1 and speed of 3000 rpm.

Fig. 8 shows the variation of volumetric efficiency at full load with equivalence ratio, ϕ in both versions of the engine with different test fuels. Volumetric efficiency is more at leaner mixtures and rich mixtures with both test fuels and with different configurations of the engine. At leaner mixtures, fuel intake is less and air intake is more leading to produce higher volumetric efficiency. At richer mixtures, charge cooling takes place due to latent heat of evaporation of fuel gives higher density of air and hence higher volumetric efficiency.

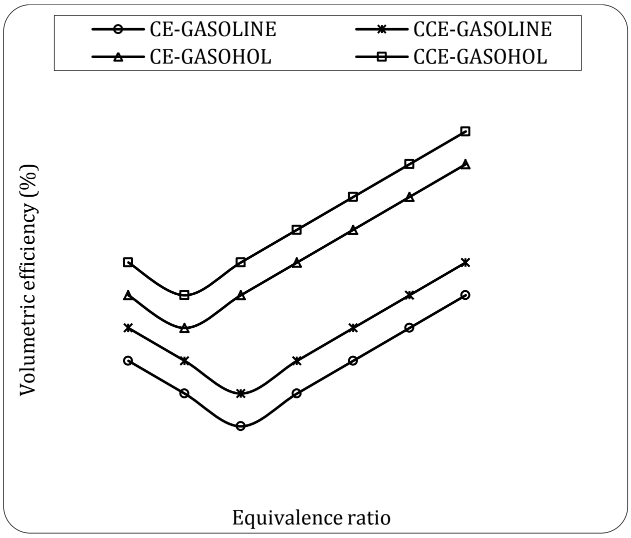


Fig.8 Variation of volumetric efficiency with Equivalent ratio in CE and CCE with both test fuels with a compression ratio of 9:1 and at a speed of 3000 rpm

Conclusions

Peak brake thermal efficiency improved by 16%, at full load–brake specific energy consumption decreased by 6%, exhaust gas temperature decreased by 18% and volumetric efficiency increased by 3% with CCE with gasohol over CE with gasoline operation. Equivalence ratio of 0.85 was found to be optimum for higher thermal efficiency with methanol blended gasoline with CCE.

Acknowledgements

Authors thank authorities of Chaitanya Bharathi Institute of Technology, Hyderabad for facilities provided. Financial assistance from Andhra Pradesh Council of Science and Technology (APCOST), Hyderabad, is greatly acknowledged.

References

Abu-Zaid., Badran, O. and Yamin, J. 2004, Effect of methanol addition on the performance of spark ignition engines, *Energy & Fuels*, 18, pp 312- 315.

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

Bahattin Celik, M. 2008, Experimental determination of suitable ethanol–gasoline blend rate at high compression ratio for gasoline engine, *Applied Thermal Engineering,* 28, pp396–404.

Ceviz, M.A. and Yu ¨ksel, F., Effects of ethanol–unleaded gasoline blends on cyclic variability and emissions in a spark ignition engine, *Applied Thermal Engineering,* Volume- 25, 917–925, 2005.

Dhandapani, S. (1991), Theoretical and experimental investigation of catalytically activated lean burnt combustion, Ph D Thesis, IIT, Chennai.

Heywood, J.B. 1988, Fundamentals of IC engines, TMH, NewYork

Indira Priyadersini, Ch., Murali Krishna, M.V.S., Nagini, Y., Ushasri, P., Krishna Murthy, P.V., and Kishor, K.2013, Comparative studies on four stroke copper coated spark ignition engine with catalytic converter with different catalysts with alcohol blended gasoline. *International Journal of Management, IT and Engineering, 3(5), 600–620*

Murali Krishna, M.V.S., and Kishor, K. 2008, Performance of copper coated spark ignition engine with methanol–blended gasoline with catalytic converter, *Indian Journal (CSIR) of Scientific and Industrial Research, 67,July,543–548.*

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

Murali Krishna, M.V.S., Kishor, K., Murthy, P.V.K., Gupta, A. V S. S. K .S., and Narasimha Kumar. S. 2011, Comparative studies on performance evaluation of four stroke copper coated spark ignition engine with catalytic converter with alcohols. *International Journal of Advances in Engineering Research,* 2(6), pp *1–11.*

Nakata, K. 2006, The effect of ethanol fuel on a spark ignition engine, *SAE Paper* No-2006-01-3380.

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

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