

Research Article

Comparative Studies on Exhaust Emissions and Combustion Characteristics of Two Stroke Copper Coated Spark Ignition Engine with Alcohol Blended Gasoline with Catalytic Converter

S. Narasimha Kumar^A, M.V.S. Murali Krishna^A and P.V.K. Murthy^{B*}^AMechanical Engineering Department, Chaitanya Bharathi Institute of Technology,, Gandipet, Hyderabad- 500 075, Andhra Pradesh, India^BJaya Prakash Narayan Educational Society Group of Institutions, Mahabubnagar-509001, Andhra Pradesh, India.

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Abstract

Experiments were conducted to control exhaust emissions and determine combustion characteristics of two-stroke, single cylinder, spark ignition (SI) engine, with alcohol blended gasoline (80% gasoline, 10% methanol, 10% ethanol by volume) having copper coated combustion chamber [CCCC, copper-(thickness, 300 μ) coated on piston crown, inner side of cylinder head] provided with catalytic converter with sponge iron as catalyst and compared with conventional SI engine (CE) with pure gasoline operation. Exhaust emissions (carbon mono oxide (CO) and un-burnt hydrocarbons (UBHC)) were evaluated at different values of brake mean effective pressure. Combustion characteristics (peak pressure, maximum rate of pressure rise and time of occurrence of peak pressure and maximum heat release) were determined at full load operation of the engine. A microprocessor-based analyzer was used for the measurement of CO/UBHC in the exhaust of the engine. Combustion characteristics were determined by special software package. Copper coated combustion chamber with alcohol blended gasoline considerably reduced pollutants in comparison with CE with pure gasoline operation. Catalytic converter with air injection significantly reduced pollutants with test fuels on both configurations of the combustion chamber. The catalyst, sponge reduced the pollutants effectively with both test fuels in both versions of the combustion chamber.

Keywords: S.I. Engine, CE, copper coated combustion chamber, Exhaust Emissions, CO, UBHC, combustion characteristics, Catalytic converter, Sponge iron, Air injection.

1. Introduction

The paper is divided into i) Introduction, ii) Materials and Methods, iii) Results and Discussions, iv) Conclusions, Research Findings, Future scope of work followed by References.

This section deals with need for alternate fuels, important substitutes for gasoline, emissions from SI engine, their formation, effect of pollutants on human health, their impact on environment, change of fuel composition and engine modification to reduce pollutants and improve the performance, methods of reducing pollutants, catalytic converter, research gaps, objective of the experimentation.

The civilization of a particular country has come to be measured on the basis of the number of automotive vehicles being used by the public of the country. The tremendous rate at which population explosion is taking place imposes expansion of the cities to larger areas and common man is forced, these days to travel long distances even for their routine works. This in turn is causing 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 petrol due to individual transport, and 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.

In the context of fast depletion of fossil fuels, the search for alternate fuels has become pertinent. Alcohols are probable candidates as alternate fuels for SI engines, as their properties are compatible close to gasoline fuels. 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 (Fulekar M H, 2004; Sharma B.K, 2004). These

*Corresponding author: P.V.K. Murthy

pollutants cause asthma, bronchitis, emphysema, slowing down of reflexes, vomiting sensation, dizziness, drowsiness, etc. Such pollutants also cause detrimental effects (Khopkar.S.M., 2005) on animal and plant life, besides environmental disorders. Age and maintenance of the vehicle are some of the reasons (Ghose M K et al 2004; Usha Madhuri T et al, 2003; Murthy, P.V.K et al 2010) for the formation of pollutants.

Engine modification (Nedunchezian N et al 2000; Murali Krishna, M.V.S et al 2010; Narasimha Kumar, S et al 2011) 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. The use of catalysts to promote combustion is an old concept. More recently copper is coated over piston crown and inside of cylinder head wall and it is reported that the catalyst improved the fuel economy and increased combustion stabilization. Catalytic converter is one of the effective (Murali Krishna, M.V.S et al 2005; Murali Krishna, M.V.S et al 2006; Murali Krishna, M.V.S et al 2008; Kishor, K et al 2010) methods to reduce pollutants in SI engine. Reduction of pollutants depended on mass of the catalyst, void ratio, temperature of the catalyst, amount of air injected in the catalytic chamber. A reduction of 40% was reported with use of sponge iron catalyst while with air injection in the catalytic chamber reduced pollutants by 60%.

Alcohol was blended (Ceviz, M.A et al 2005; Bahattin Celik, M 2008; Al-Baghdadi 2008) with gasoline to reduce pollutants and improve the performance. CO and UBHC emissions reduced with blends of alcohol with gasoline. The present paper reported the control of exhaust emissions and determination of combustion characteristics of copper coated combustion chamber with alcohol blended gasoline (gasoline-80%, methanol-10% and ethanol-10% by volume) and compared with pure gasoline operation on CE. Exhaust emissions of CO and UBHC were controlled by catalytic converter with sponge iron as catalyst.

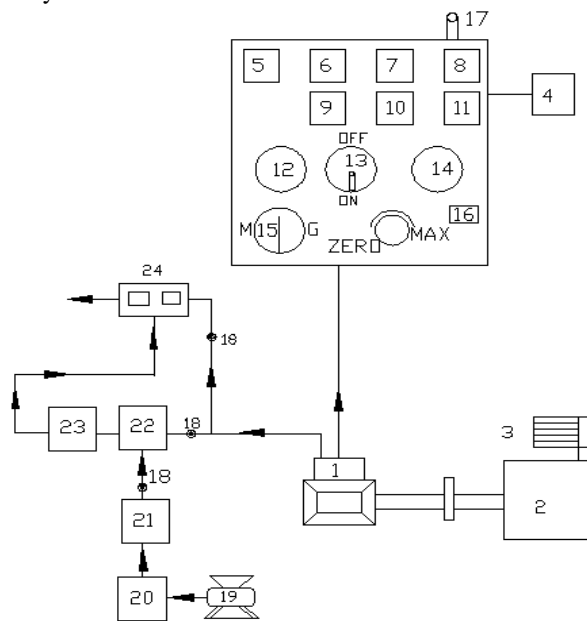
2. Materials and Methods

This section deals with fabrication of copper coated combustion chamber, description of experimental set up, operating conditions of catalytic converter and definition of used values

In catalytic coated combustion chamber, crown of the piston and inner surface of cylinder head are coated with copper by flame spray gun. The surface of the components to be coated are cleaned and subjected to sand blasting. A bond coating of nickel- cobalt- chromium of thickness 100 microns is sprayed over which copper (89.5%), aluminium (9.5%) and iron (1%) alloy of thickness 300 microns is coated with METCO flame spray gun. The coating has very high bond strength and does not wear off even after 50 h of operation.

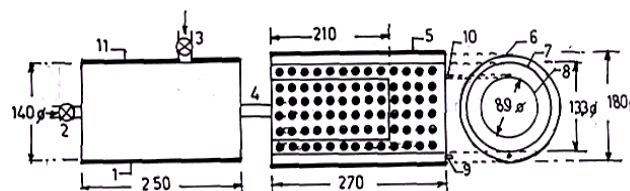
Figure.1. shows experimental set-up used for investigations. A two- stroke, single-cylinder, air -cooled, SI engine (brake power 2.2 kW at a speed of 3000 rpm) was coupled to a rope brake dynamometer for measuring its brake power. Speed was measured with speed sensor

and torque with torque sensor. Compression ratio of engine is 7.5:1. Exhaust gas temperature, speed, torque, fuel consumption and air flow rate of the engine were measured with electronic sensors. The diameter and stroke of the cylinder were 57 mm each. Recommended spark ignition timing was 25°aTDC. CO and UBHC emissions in engine exhaust were measured with Netel Chromatograph analyzer.



1. Engine, 2.Electrical swinging field dynamometer, 3. Loading arrangement, 4.Fuel tank, 5.Torque indicator/controller sensor, 6. Fuel rate indicator sensor, 7. Hot wire gas flow indicator, 8. Multi channel temperature indicator, 9. Speed indicator, 10. Air flow indicator, 11. Exhaust gas temperature indicator, 12. Mains ON, 13. Engine ON/OFF switch, 14. Mains OFF, 15. Motor/Generator option switch, 16. Heater controller, 17. Speed indicator, 18. Directional valve, 19. Air compressor, 20. Rotometer, 21. Heater, 22. Air chamber, 23. Catalytic chamber, 24. CO/HC analyzer,

Fig.1 Schematic Diagram of Experimental set up



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 (Figure.2) was fitted to exhaust pipe of engine. Provision was also made to inject a definite quantity of air into catalytic converter. Air quantity drawn from compressor and injected into converter was kept constant so that backpressure do not increase. Experiments were carried out on CE and copper coated combustion chamber with different test fuels [pure gasoline and

alcohol blended gasoline (20% by vol)] 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.

Definitions of used values:

Brake mean effective pressure: It is defined as specific torque of the engine. Its unit is bar.

$$BP = \frac{BMEP \times 10^5 \times L \times A \times n \times k}{60000}$$

BP = Brake power of the engine in kW;

BMEP= Brake mean effective pressure of the engine in bar

L= Stroke of the piston in m

A= Area of the piston = $\frac{3.14 \times D^2}{4}$, Where D= Bore of the cylinder in m

n= Effective number of power cycles = $\frac{N}{2}$, where N=Speed of the engine = 3000 rpm

3. Results and Discussion

This section deals with determination of exhaust emissions and combustion characteristics

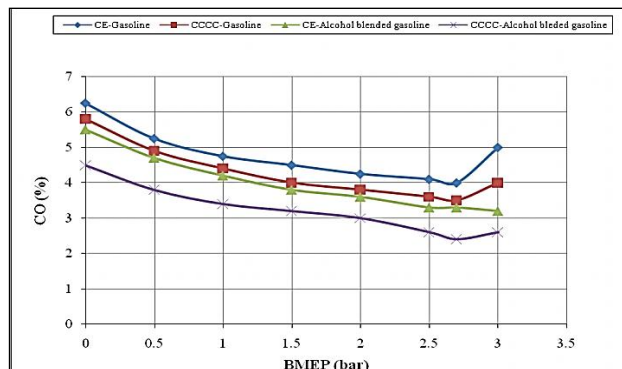
3.1 Exhaust Emissions

This section deals with variation of CO emissions and UBH emissions with BMEP. This also contained data of CO and UBHC emissions at different operating conditions of the catalytic converter.

Figure. 3 shows the variation of CO emissions with BMEP in different versions of the engine with both pure gasoline and alcohol blended gasoline. CO emissions decreased with alcohol blended gasoline at all loads when compared to pure gasoline operation on copper coated combustion chamber and CE, as fuel-cracking reactions [10] were eliminated with alcohol.. The combustion of methanol or ethanol produces more water vapor than free carbon atoms as methanol has lower C/H ratio of 0.25, while with ethanol 0.33, against 0.50 of gasoline. Methanol or ethanol 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 or ethanol 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.

Copper coated combustion chamber reduced 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 were observed with Reference with pure gasoline operation on copper coated combustion chamber.



CE- conventional engine: CCCC-Copper coated combustion chamber, CO- Carbon monoxide emissions: BMEP-Brake mean effective pressure

Fig.3 Variation of CO emissions with BMEP in different versions of the combustion chamber with pure gasoline and alcohol blended gasoline at a compression ratio of 7.5:1 and speed of 3000 rpm

Table 1 Data of ‘Co’ Emissions (%) With Different Test Fuels With Different Configurations of The Combustion Chamber At Different Operating Conditions Of The Catalytic Converter At A Compression Ratio Of 7.5:1 And Speed Of 3000 Rpm.

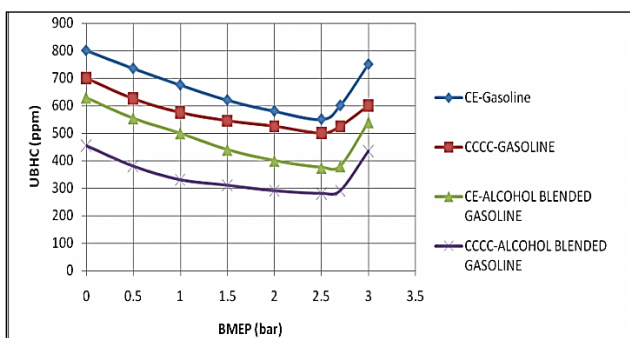
Set	Conventional Engine (CE)		Copper Coated Combustion Chamber (CCCC)	
	Pure Gasoline	Alcohol blended gasoline	Pure Gasoline	Alcohol blended gasoline
Set-A	5	3.2	4	2.6
Set-B	3	2	2.4	1.6
Set-C	2	1.3	1.6	1.1

Set-A- Without catalytic converter and without air injection, Set-B: With catalyst and without air injection, Set-C: With catalyst and with air injection

Table-1 shows the data of CO emissions with different test fuels with different configurations of the combustion chamber at different operating conditions of the catalytic converter with different catalysts. From the table, it can be observed that CO emissions decreased considerably with catalytic operation in set-B with alcohol blended gasoline and further decrease in CO is pronounced with air injection with the same fuel. The effective combustion of the alcohol blended gasoline itself decreased CO emissions in both configurations of the combustion chamber. CO emissions were observed to be higher with alcohol blended gasoline operation in comparison with pure gasoline operation in both versions of the combustion chamber at different operating conditions of the catalytic converter. This is due to the reason that C/H ratio of alcohol blended gasoline is lower in comparison with that of pure gasoline operation.

Figure 4 shows the variation of un-burnt hydro carbon emissions (UBHC) with BMEP in different versions of the combustion chamber with both test fuels. UBHC emissions followed the similar trends as CO emissions in copper coated combustion chamber and CE with both test fuels, due to increase of flame speed with catalytic activity and reduction of quenching effect with copper coated combustion chamber.

Two stroke engines which are scavenged by fresh charge have higher fuel consumption due to opening of inlet and exhaust port at some time and some of fresh charge escapes without doing any work releasing un-burnt hydro carbons.



CE- conventional engine; CCCC-Copper coated combustion chamber, UBHC- Un-burnt hydro carbons; BMEP-Brake mean effective pressure

Fig. 4 Variation of UBHC emissions with BMEP in different versions of the combustion chamber with pure gasoline and alcohol blended gasoline at a compression ratio of 7.5:1 and speed of 3000 rpm

Table 2 Data Of ‘UBHC’ Emissions (PPM) With Different Test Fuels With Different Configurations Of The Combustion Chamber At Different Operating Conditions Of The Catalytic Converter At A Compression Ratio Of 7.5:1 And Speed Of 3000 Rpm.

Set	Conventional Engine (CE)		Copper Coated Combustion Chamber (CCCC)	
	Pure Gasoline	Alcohol blended gasoline	Pure Gasoline	Alcohol blended gasoline
Set-A	750	540	600	435
Set-B	450	330	360	260
Set-C	300	215	240	175

Set-A- Without catalytic converter and without air injection, Set-B: With catalyst and without air injection, Set-C: With catalyst and with air injection

Table-2 shows the data of UBHC emissions with different test fuels with different configurations of the combustion chamber at different operating conditions of the catalytic converter with sponge iron. The trends observed with UBHC emissions are similar to those of CO emissions in both versions of the engine with both test fuels. From Table, it is observed that catalytic converter reduced UBHC emissions considerably with both versions of the

combustion chamber and air injection into catalytic converter further reduced pollutants. In presence of catalyst, pollutants further oxidised to give less harmful emissions like CO₂. Similar trends are observed with Reference with pure gasoline operation on CCE.

3.2 Combustion characteristics

Figure.5 (a) presents bar charts showing the variation of peak pressure with test fuels with different versions of the combustion chamber. Peak pressures were observed to be higher with alcohol blended gasoline in comparison with pure gasoline in both versions of the combustion chamber.

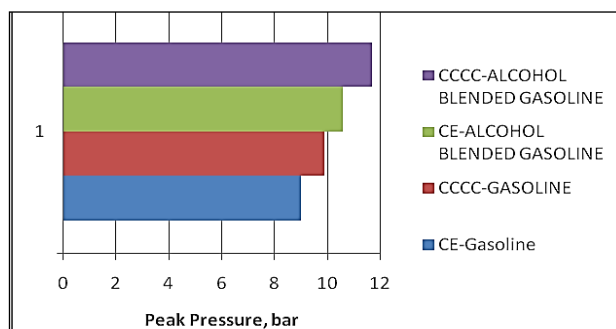


Fig.5 (a) Variation of PP for test fuels for different configurations of the engine

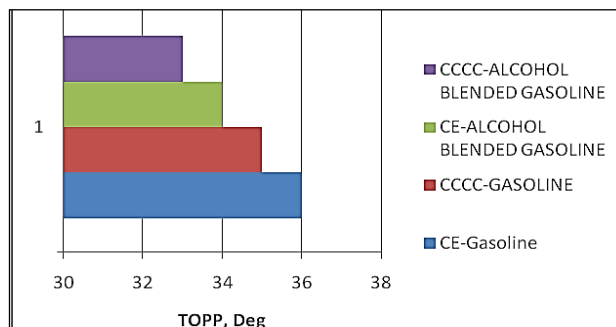


Fig.5. (b) Variation of TOPP for test fuels for different configurations of the engine

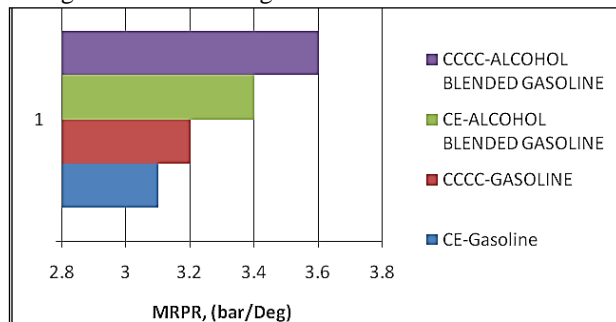


Fig.5 (c) Variation of MRPR for test fuels for different configurations of the engine

Assuming all the fuel enter the engine completely evaporated, the fuel giving largest number of moles of product per mole of reactant should produce the greatest pressure in the cylinder after the combustion, all other

factors being equal (which incidentally are not) The greater pressure taken alone would results in an increase in engine power. But an engine may not ingest its mixture with the fuel already evaporated. Under such conditions the number of moles of products should be examined on the basis of number of moles of air inducted since fuel occupies very little volume. Alcohol blended gasoline produced more number of moles of products on dry and wet basis.

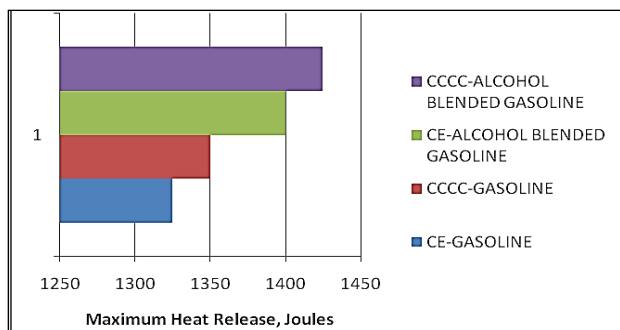


Fig. 5 (d) Variation of maximum heat release for test fuels for different configurations of the engine

Figure.5 Variation of combustion characteristics for test fuels for different configurations of the combustion chamber.

Figure.5 (b) presents the bar charts showing the variation of time of occurrence of peak pressure (TOPP) in both versions of the combustion chamber with test fuels. TOPP was found to be lower (nearer to TDC) with CCE with alcohol blended gasoline compared with CE with pure gasoline, which confirms that performance was improved with efficient combustion with CCE. This is because CE exhibited higher temperatures of combustion chamber walls leading to continuation of combustion, giving peak pressures away from TDC. However, this phenomenon is nullified with CCE with alcohol blended gasoline because of reduced temperature of combustion chamber walls thus bringing the peak pressures closure to TDC.

CE with gasoline operation exhibited pressure on the piston by the time the piston already started executing downward motion from TDC to BDC leading to decrease PP and increase TOPP. Copper coated combustion chamber with alcohol blended gasoline operation improved combustion due to catalytic activity, PP was observed to be higher than CE with same test fuel. Higher PP and lower TOPP confirmed that performance of the copper coated combustion chamber with alcohol blended gasoline operation improved causing efficient energy utilization on the piston.

Alcohol addition improved the combustion process, reduces the crevices flow energy, reduces the cylinder temperature, reduces the ignition delay, speeds up the flame front propagation, and reduces the duration of combustion.

The trend followed by MRPR was similar to that of PP as indicated in Figure. 5c. The increase in maximum heat release (calculated from heat release diagram obtained

from software package) indicates (Figure.5(d)) that the combustion in the copper coated combustion chamber with alcohol blended gasoline was improved when compared with CE with gasoline due to the combustion of the relatively lean air- fuel mixtures, which shows that combustion was efficient with CCE with gasohol.

4. Conclusions

1. Thermal efficiency increased by 9% with gasoline operation, while with alcohol blended gasoline operation it increased by 8%.
2. Exhaust gas temperature decreased by 19%, with gasoline operation, while with alcohol blended gasoline operation it decreased by 5%.
3. Volumetric efficiencies were compatible with gasoline operation as well as alcohol blended gasoline operation.
4. CO and UBHC emissions at full load operation decreased by 20% with CCE when compared with CE with both test fuels.
5. Set-B operation decreased CO and UBHC emissions by 40%, while Set-C operation decreased these emissions by 60% with test fuels when compared to Set-A operation.
6. Sponge iron is proved to be more effective in reducing the pollutants.
7. Peak pressure increased by 11% with gasoline operation, while with alcohol blended gasoline it increased by 10%.
8. Both MRPR and TOPP were compatible
9. Maximum heat release rate increased by 2% with gasoline operation, while with alcohol blended gasoline, it increased by 2%.

4.1 Research Findings and Future Scope of Work

Investigations on control of exhaust emissions and combustion characteristics in two-stroke SI engine were systematically carried out. Spark plug timing can be varied to improve the performance further and reduce pollutants more effectively.

Acknowledgements

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