Comparative Studies on Exhaust Emissions from Two Stroke Copper Coated Spark Ignition Engine with Gasohol

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Abstract - Experiments were conducted to control the exhaust emissions from two-stroke, single cylinder, spark ignition (SI) engine, with alcohol blended gasoline (80% gasoline, 20% 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 of CO and UBHC were evaluated at different values of brake effective pressure. A microprocessor-based analyzer was used for the measurement of CO/UBHC in the exhaust of the engine. Copper coated combustion chamber with alcohol blended gasoline considerably reduced pollutants in comparison with CE with pure gasoline operation.
KEYWORDS: S.I. Engine, CE, copper coated combustion chamber, Exhaust Emissions, CO, UBHC, aldehydes, Catalytic converter, Sponge iron, Air injection

I. 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 exhaust emissions from SI engine, their formation, effect of pollutants on human health, their impact on environment, change of fuel composition to reduce pollutants, engine modification to improve the performance and reduce pollutants, methods of reducing pollutants, catalytic converter, research gaps, objective of the experimentation.

Carbon monoxide (CO) and un-burnt hydrocarbons (UBHC), major exhaust pollutants formed due to incomplete combustion of fuel, cause many human health disorders [1-2]. These pollutants cause asthma, bronchitis, emphysema, slowing down of reflexes, vomiting sensation, dizziness, drowsiness, etc. Such pollutants also cause detrimental effects [3] on animal and plant life, besides environmental disorders. Age and maintenance of the vehicle are some of the reasons [4-5] for the formation of pollutants. Aldehydes which are intermediate compounds [6] formed in combustion, are carcinogenic in nature and cause detrimental effects on human health and hence control of these pollutants is an immediate task.

Engine modification [7-9] 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 [10-13] 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 [14-16] with gasoline to reduce pollutants. CO and UBHC emissions reduced with blendes of alcohol with gasoline.

The present paper reported the control of exhaust emissions of CO, UBHC and aldehydes (formaldehydes and acetaldehydes) from two stroke SI engine with alcohol blended gasoline in different configurations of the combustion chamber with catalytic converter with sponge iron as catalyst and compared with gasoline operation on CE.

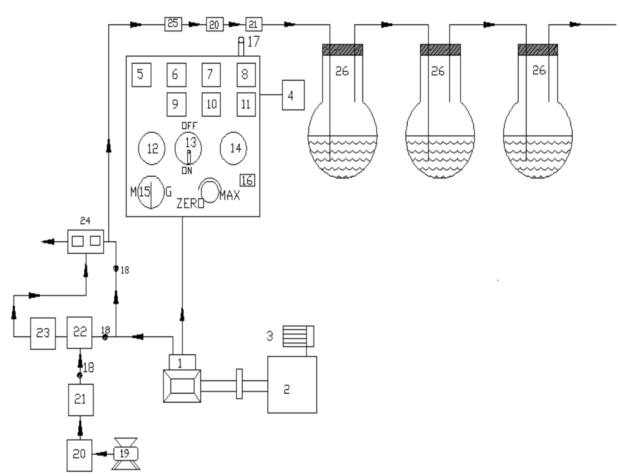
II. MATERIALS AND METHODS

This section deals with fabrication of copper coated combustion chamber, description of experimental set up, operating conditions of catalytic converter and method of measuring aldehydes 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 [7].

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^{o}aTDC.

CO and UBHC emissions in engine exhaust were measured with Netel Chromatograph analyzer.

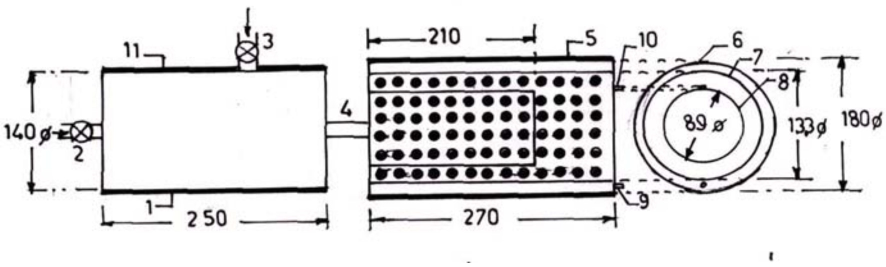


1. Engine, 2.Electrical swinging field dynamometer, 3. Loading arrangement, 4.Fuel tank, 5.Torque indicator/controller sensor, 6. Fuel rate indicator sensor, 7. Hot wire gas flow indicator, 8. Multi channel temperature indicator, 9. Speed indicator, 10. Air flow indicator, 11. Exhaust gas temperature 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, 25. Filter, 26. Round bottom flasks containing DNPH solution,

Fig.1 Schematic Diagram of Experimental set up

A catalytic converter [11] (Figure.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 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. Air fuel ratio is varied so as to obtain different equivalence ratios.

For measuring aldehydes in the exhaust of the engine, a wet chemical method [6] is employed. The exhaust of the engine is bubbled through 2,4-dinitrophenyl hydrazine (DNPH) in hydrochloric acid solution and the hydrazones formed from aldehydes are extracted into chloroform and are analyzed by high performance liquid chromatography (HPLC) to find the percentage concentration of formaldehyde and acetaldehyde in the exhaust of the engine.



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

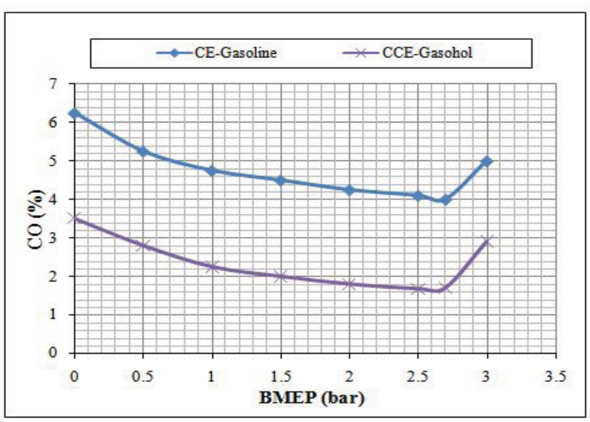
Fig.2. Details of Catalytic converter

III. RESULTS AND DISCUSSION

This section deals with variation of CO emissions and UBHC emissions with brake mean effective pressure (BMEP) of the engine, variation of CO emissions and UBHC emissions with equivalence ratio and control of these pollutions along with aldehydes with 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 [13] were eliminated with alcohol.. The combustion of 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. 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. 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 CO_2 and also CO to CO_2 thus makes leaner mixture more combustible, causing reduction of CO emissions.

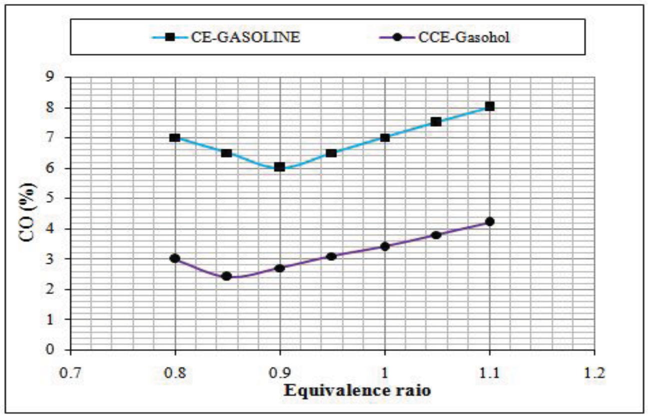
Copper coated combustion chamber reduced CO emissions in comparison with CE. Copper or its alloys acts as catalyst in combustion chamber, whereby facilitates effective combustion of fuel leading to formation of CO_2 instead of CO. Similar trends were observed with Reference [7] with pure gasoline operation on copper coated combustion chamber.



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

Figure. 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

Figure.4 shows the variation of CO emissions with equivalence ratio, ϕ in both configurations of the engine with pure gasoline and alcohol blended gasoline. At leaner mixtures marginal increased CO emissions, and rich mixtures drastically increased CO emissions with both test fuels in different configurations of the combustion chamber. With alcohol blended gasoline operation, minimum CO emissions were observed at ϕ = 0.85, and with pure gasoline operations, minimum CO emissions are observed at ϕ = 0.9 with both configurations of the engine. This was due to lower value of stoichiometric air requirement of alcohol blended gasoline when compared with gasoline. Very rich mixtures have incomplete combustion. Some carbon only burns to CO and not to CO_2.



CE- conventional engine: CCCC-Copper coated combustion chamber, CO- Carbon monoxide emissions:

Figure. 4 Variation of CO emissions with Equivalence ratio in both versions of the combusiton chamber with different test fuels with a compression ratio of 7.5:1 at a speed of 3000 rpm

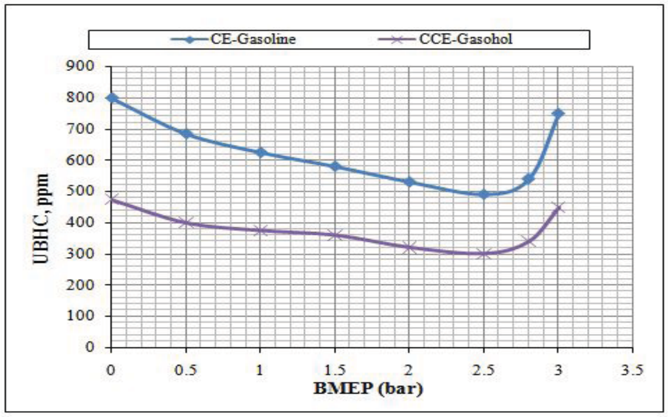
Table-1 shows the data of CO emissions with different test fuels with different configurations of the combustion chamber at different operating conditions of the catalytic converter with different catalysts. From the table, it can be observed that CO emissions deceased considerably with catalytic operation 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

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 FULL LOAD OPERATION AT A COMPRESSION RATIO OF 7.5:1 AND SPEED OF 3000 RPM

Set	Gasoline (CE)	Gasohol(CCE)
Set-A	5	2.6
Set-B	3	1.6
Set-C	2.0	1.1

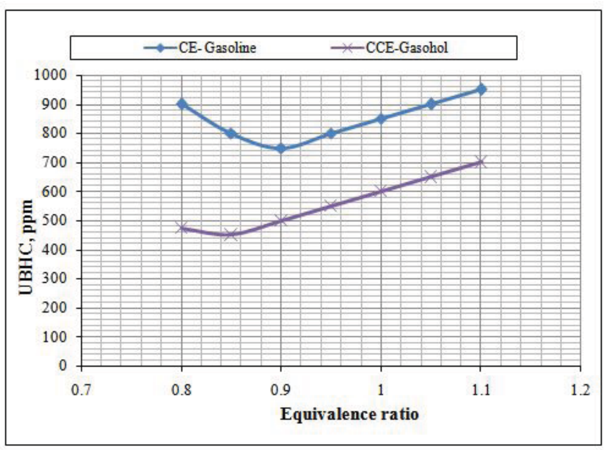
Figure.5 shows the variation of un-burnt hydro carbon emissions (UBHC) with BMEP in different versions of the combustion chamber with both test fuels. UBHC emissions followed the similar trends as CO emissions in copper coated combustion chamber and CE with both test fuels, due to increase of flame speed with catalytic activity and reduction of quenching effect with copper coated combustion chamber.



CE- conventional engine: CCCC-Copper coated combustion chamber, UBHC- Un-burnt hydro carbons: BMEP-Brake mean effective pressure
Figure. 5 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

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.

Figure.6 shows the variation of UBHC emissions with equivalence ratio, ϕ with pure gasoline and alcohol blended gasoline with both configurations of the combustion chamber. The trends followed by UBHC emissions are similar to those of CO emissions. Drastic increase of UBHC emissions was observed at rich mixtures with both test duels in different configurations of the combustion chamber. In the rich mixture some of the fuel will not get oxygen and will not burn. During starting from the cold, rich mixture was supplied to the engine, hence marginal increase of UBHC emissions was observed at lower value of equivalence ratio.



CE- conventional engine: CCCC-Copper coated combustion chamber, UBHC-Un-burnt hydro carbons

Figure. 6 Variation of UBHC emissions with Equivalence ratio in both versions of the combustion chamber with different test fuels with a compression ratio of 7.5:1 at a speed of 3000 rpm

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 were similar to those of CO emissions in both versions of the combustion chamber 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 CO_2. Similar trends are observed with Reference [7] with pure gasoline operation on copper coated combustion chamber.

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 Full Load Operation At A Compression Ratio Of 7.5:1 And Speed Of 3000 Rpm.

Set	Gasoline (CE)	Gasohol(CCE)
Set-A	750	435
Set-B	450	260
Set-C	300	175

TABLE-3

Data Of Formaldehyde Emissions (% Concentration) With Different Test Fuels Withdifferent 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	CE-Gasoline	CCE-Gasohol
Set-A	9.1	9.3
Set-B	6.3	5.0
Set-C	3.5	3.9

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-4

Data Of Acetaldehyde Emissions (% Concentration) With Different Test Fuels With Different Configurations Of The Combustion Chamber At Different Operating Conditions Of The Catalytic Converter

Set	CE-Gasoline	CCE-Gasohol
Set-A	7.7	12.6
Set-B	4.9	7.5
Set-C	2.1	5.2

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

IV.CONCLUSION

1. CO and UBHC emissions at full load operation decreased by 17% and 20%with CCE when compared with CE with gasoline.
2. With copper coated combustion chamber, formaldehyde emissions decreased by 40% in comparison with pure gasoline operation on CE.
3. With copper coated combustion chamber, acetaldehyde emissions decreased by 63% in comparison with pure gasoline operation on CE.
4. Set-B operation decreased CO, UBHC and aldehyde emissions by 40%, while Set-C operation decreased these emissions by 60% with test fuels when compared with Set-A operation.
5. Sponge iron is proved to be more effective in reducing the pollutants.

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