International Journal of Scientific & Technology Research Volume 1, Issue 2, March 2012 **ISSN 2277-8616**

Comparative Studies on Emissions from Two Stroke Copper Coated Spark Ignition Engine with Alcohols with Catalytic Converter

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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% methanol by vol; 80% gasoline and 20% ethanol by volume) having copper coated engine [CCE, copper-(thickness, 300 μ) coated on piston crown, inner side of cylinder head] provided with catalytic converter with different catalysts such as sponge iron and manganese ore and compared with conventional engine (CE) with pure gasoline operation. A microprocessor-based analyzer was used for the measurement of carbon monoxide (CO) and un-burnt hydro carbon (UBHC) in the exhaust of the engine at various magnitudes of brake mean effective pressure. Aldehydes were measured by DNPH (dinitrophenyl hydrazine) method. CCE with alcohol blended gasoline considerably reduced emissions in comparison with CE with pure gasoline operation. Catalytic converter with air injection significantly reduced pollutants with test fuels on both configurations of the engine. The catalyst, sponge iron in comparison with manganese ore reduced the pollutants effectively with both test fuels in both versions of the engine. Methanol blended gasoline effectively reduced pollutants in comparison with ethanol blended gasoline.

Index Terms— S.I. Engine, CE, CCE, Emissions, Catalytic converter, Sponge iron, Manganese ore, Air injection

NOMENCLATURE

ϕ	Fuel-equivalence ratio,
BMEP	Brake mean effective pressure in bar
C	Number of carbon atoms in fuel composition
CCE	Copper coated engine
CE	Conventional engine
CO	Carbon monoxide
CO_2	Carbon dioxide
DNPH	Dinitrophenyl hydrazine
Gasohol	20% of ethanol blended with 80% of gasoline by volume
H	Number of hydrogen atoms in fuel composition
HPLC	High performance liquid chromatography
M	Manganese ore
METCO	A Trade name
S	Sponge iron
Set-A	Without catalyst and without air injection
Set-B	With catalyst and without air injection
Set-C	With air injection and with catalyst
SI	Spark ignition
UBHC	Un-burnt hydro-carbons

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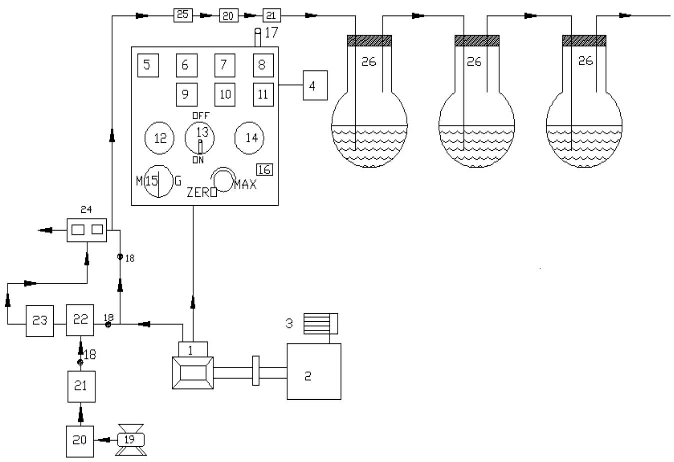
1. INTRODUCTION

CO and UBHC, major exhaust emissions formed due to incomplete combustion of fuel, cause many human health disorders [1,2]. Such emissions 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 improved engine performance as copper is a good conductor of heat and combustion improved with copper coating. Catalytic converter was effective[10-14] in reduction of emissions in SI engine. The present paper reported the control of emissions of CO, UBHC, and aldehydes from the exhaust of two-stroke SI engine with alcohol blended gasoline in different configurations of the engine with catalytic converter with different catalysts such as sponge iron (S) and manganese ore (M) and compared with pure gasoline operation on CE. The performance of the catalyst was compared with one over the other.

2. MATERIALS AND METHODS

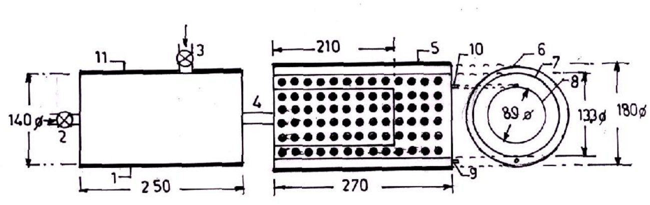
Fig.1 showed experimental set-up used for investigations. A two- stroke, single-cylinder, air -cooled, SI engine (brake power 2.2 kW at the speed of 3000 rpm) was coupled to a rope brake dynamometer for measuring its brake power. Speed was measured with speed sensor and torque with torque sensor. Compression ratio of engine was 7.5:1. Exhaust gas temperature, speed, torque, fuel consumption and air flow rate of the engine were measured with electronic sensors.



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 Experimental set up

In catalytic coated engine, piston crown and inner surface of cylinder head were coated with copper by flame spray gun. The surface of the components to be coated were cleaned and subjected to sand blasting. A bond coating of nickel- cobalt- chromium of thickness 100 microns was sprayed over which copper (89.5%), aluminium (9.5%) and iron (1%) alloy of thickness 300 microns was coated with METCO flame spray gun. The coating had very high bond strength and did not wear off even after 50 h of operation[7]. CO and UBHC emissions in engine exhaust were measured with Netel Chromatograph analyzer at various magnitudes of BMEP. A catalytic converter [11] (Fig.2) was fitted to exhaust pipe of 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

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 did not increase. Experiments were carried out on CE and CCE with different test fuels [pure gasoline, ethanol blended gasoline [gasohol], methanol blended gasoline (20% by volume)] under different operating conditions of catalytic converter like Set-A, Set-B and Set-C. Air fuel ratio was varied so as to obtain different equivalence ratios. For measuring aldehydes in the exhaust of the engine, a wet chemical method[6] was employed. The exhaust of the engine was bubbled through 2,4 DNPH in hydrochloric acid solution and the hydrazones formed from aldehydes were extracted into chloroform and were analyzed by HPLC to find the percentage concentration of formaldehyde and acetaldehyde in the exhaust of the engine.

3. RESULTS

Fig. 3-Variation of CO emissions with BMEP in different versions of the engine with both pure gasoline and methanol blended gasoline.

Fig.4-Variation of CO emissions with equivalence ratio, ϕ in both configurations of the engine with pure gasoline and methanol blended gasoline.

Fig.5- Variation of un-burnt hydro carbon emissions (UBHC) with BMEP in different versions of the engine with both test fuels.

Fig. 6- Variation of UBHC emissions with equivalence ratio, ϕ with pure gasoline and methanol blended gasoline with both configurations of the engine

Table.1- Data of CO emissions (%) with different test fuels with different configurations of the engine at different operating conditions of catalytic converter with different catalysts

Table.2- Data of UBHC emissions (ppm) with different test fuels with different configurations of the engine at different operating conditions of catalytic converter with different catalysts

Table.3-Data of Formaldehyde emissions (% Concentration) with different test fuels with different configurations of the engine at different operating conditions of catalytic converter with different catalysts

Table.4-Data of Acetaldehyde emissions (%Concentration) with different test fuels with different configurations of the engine at different operating conditions of catalytic converter with different catalysts

4. DISCUSSION

From Fig.3, it could be observed that methanol blended gasoline decreased CO emissions at all loads when compared to pure gasoline operation on CCE and CE, as fuel-cracking reactions were eliminated with methanol. The combustion of methanol produces more water vapor than free carbon atoms as methanol has lower C/H ratio of 0.25

against 0.50 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 CO_2 and also CO to CO_2 thus makes leaner mixture more combustible, causing reduction of CO emissions. CCE reduced CO emissions in comparison with CE. Copper or its alloys acted as catalyst in combustion chamber, whereby facilitated 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 CCE.

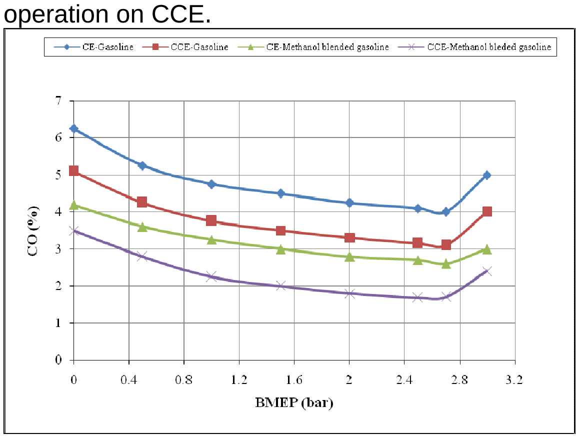


Fig. 3 Variation of CO emissions with BMEP in different versions of the engine with pure gasoline and methanol blended gasoline at a compression ratio of 7.5:1 and speed of 3000 rpm

From Fig.4, it could be noticed that at leaner mixtures marginal increase in CO emissions, and at rich mixtures drastic increase in CO emissions were observed with both test fuels

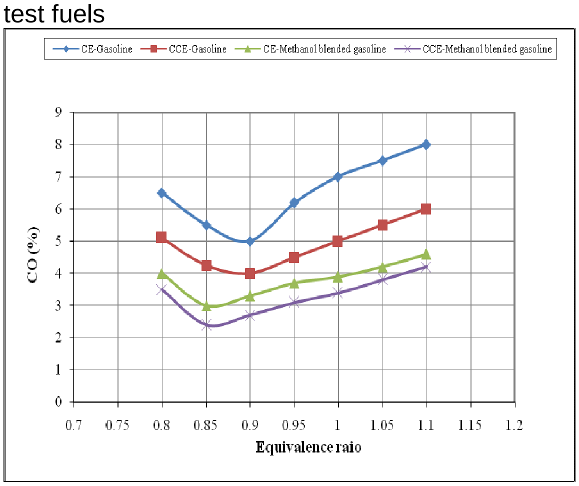


Fig. 4 Variation of CO emissions with Equivalence ratio in both versions of the engine with different test fuels with a compression ratio of 7.5:1 at a speed of 3000 rpm

In different configurations of the engine. With methanol blended gasoline operation minimum CO emissions were observed at ϕ = 0.85, and with pure gasoline operations, minimum CO emissions were observed at ϕ = 0.9 with both configurations of the engine. This was due to lower value of stoichiometric air requirement of methanol blended gasoline when compared with gasoline. Very rich mixtures have incomplete combustion. Some carbon only burns to CO and not to CO_2. From the Table-1, it could be observed that CO emissions deceased considerably with catalytic operation in set-B with methanol blended gasoline and further decrease in CO was pronounced with air injection with the same fuel. The effective combustion of the methanol blended gasoline itself decreased CO emissions in both configurations of the engine. Sponge iron decreased CO emissions effectively when compared with the manganese ore in both versions of the engine with test fuels. CO emissions were observed to be more with gasohol operation in comparison with methanol blended gasoline in both versions of the engine at different operating conditions of the catalytic converter. This was due to the reason that C/H ratio of gasohol is higher (0.33) in comparison with methanol blended gasoline 0.25).

TABLE-1 DATA OF 'CO' EMISSIONS (%)

Set	Conventional Engine (CE)						Copper Coated Engine (CCE)					
	Pure Gasoline		Methanol blended gasoline		Gasohol		Pure Gasoline		Methanol blended gasoline		Gasohol	
	S	M	S	M	S	M	S	M	S	M	S	M
Set-A	5.0	5.0	3.0	3.0	3.5	3.5	4.0	4.0	2.4	2.4	2.9	2.9
Set-B	3.0	4.0	1.8	2.1	2.3	2.8	2.4	3.2	1.44	1.92	1.9	2.32
Set-C	2.0	3.0	1.2	1.5	1.5	2.1	1.6	2.4	0.96	1.44	1.26	1.74

From Fig.5, it could be observed 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.

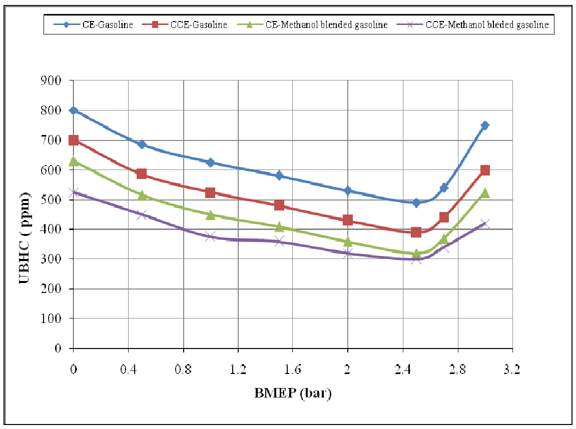


Fig. 5 Variation of UBHC emissions with BMEP in different versions of the engine with pure gasoline and methanol blended gasoline at a compression ratio of 7.5:1 and speed of 3000 rpm

From Fig. 6, it could be seen that the trends followed by UBHC emissions were similar to those of CO emissions.

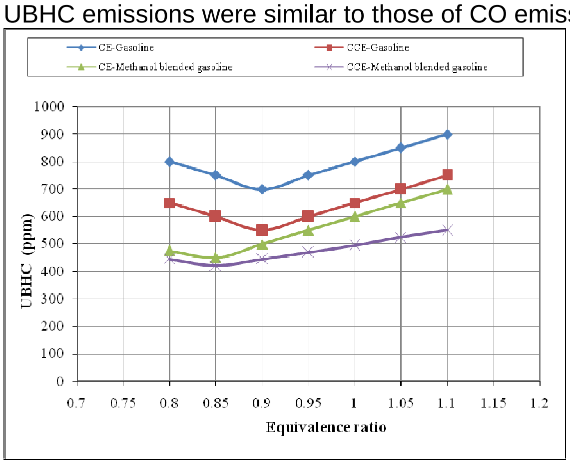


Fig. 6 Variation of UBHC emissions with Equivalence ratio in both versions of the engine with different test fuels with a compression ratio of 7.5:1 at a speed of 3000 rpm

Drastic increase of UBHC emissions was observed at rich mixtures with both test duels in different configurations of the engine. In the rich mixture some of the fuel would not get oxygen and would be completely wasted. 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. From Table-2, it could be noticed that the trends observed with UBHC emissions were similar to those of CO emissions in both versions of the engine with both test fuels. Catalytic converter reduced pollutants considerably with CE and CCE and air injection into catalytic converter further reduced pollutants. In presence of catalyst, emissions got further oxidised to give less harmful emissions like CO_2. Similar trends were observed with Reference[7] with pure gasoline operation on CCE. Sponge iron was proved to be more effective in reducing UBHC emissions in both versions of the engine with different test fuels when compared with manganese ore in both versions of the engine with different configurations of the engine. Gasohol operation increased UBHC emissions marginally in comparison with methanol blended gasoline in both versions of the engine.

TABLE-2 DATA OF UBHC EMISSIONS (ppm)

Set	Conventional Engine (CE)						Copper Coated Engine (CCE)					
	Pure Gasoline		Methanol blended gasoline		Gasohol		Pure Gasoline		Methanol blended gasoline		Gasohol	
	S	M	S	M	S	M	S	M	S	M	S	M
Set-A	750	750	525	525	562	562	600	600	420	420	450	450
Set-B	450	600	315	420	340	450	360	480	252	335	270	360
Set-C	300	450	210	315	225	330	240	360	168	250	180	270

From Table-3 and Table-4, it could be noticed that the formaldehyde emissions in the exhaust decreased considerably with the use of catalytic converter, which was more pronounced with an air injection into the converter. Methanol blend increased formaldehyde emissions considerably due to partial oxidation compared to pure gasoline. The low combustion temperature lead to produce partially oxidized carbonyl (aldehyde) compounds with gasohol. CCE decreased formaldehyde emissions when compared to CE. The trend exhibited by acetaldehyde emissions was same as that of formaldehyde emissions. However, acetaldehyde emission was observed to be more with ethanol blend compared to methanol blend of gasoline in both versions of the engine (Table-4).

TABLE-3 DATA OF FORMALDEHYDE EMISSIONS (% CONCENTRATION)

Set	Conventional Engine (CE)						Copper Coated Engine (CCE)					
	Pure Gasoline		Methanol blended gasoline		Gasohol		Pure Gasoline		Methanol blended gasoline		Gasohol	
	S	M	S	M	S	M	S	M	S	M	S	M
Set-A	9.1	9.1	23.6	23.6	14.6	14.6	6.8	6.8	13.6	13.6	9.31	9.31
Set-B	6.3	8.2	10.8	12.6	7.0	9.2	4.1	5.9	10.2	12	5.0	7.1
Set-C	3.5	5.5	8.0	10.1	5.9	7.7	3.2	5	3.5	5	3.93	5.8

TABLE-4 DATA OF ACETALDEHYDE EMISSIONS (% CONCENTRATION)

Set	Conventional Engine (CE)						Copper Coated Engine (CCE)					
	Pure Gasoline		Methanol blended gasoline		Gasohol		Pure Gasoline		Methanol blended gasoline		Gasohol	
	S	M	S	M	S	M	S	M	S	M	S	M
Set-A	7.7	7.7	12.3	12.3	16.8	16.8	4.9	4.9	9.3	9.3	12.6	12.6
Set-B	4.9	7.2	6.5	8.5	8.4	10.5	3.5	5.3	7.7	9.5	7.5	9.3
Set-C	2.1	4.3	3.8	5.6	7.0	9.1	1.4	3.1	3.9	5.6	5.2	7.2

The partial oxidation of ethanol during combustion predominantly leads to formation of acetaldehyde. Copper (catalyst) coated engine decreased aldehydes emissions considerably by effective oxidation when compared to CE. Catalytic converter with air injection drastically decreased aldehyde emissions in both versions of the engine due to oxidation of residual aldehydes in the exhaust.

5. CONCLUSIONS

CO emissions in exhaust decreased by 40% with sponge iron, while they decreased by 20% with manganese ore in CE with pure gasoline operation. These pollutants decreased by 20% with CCE when compared to CE with both test fuels. Set-B operation decreased CO and UBHC emissions by 40% each, while Set-C operation decreased these emissions by 60% with test fuels when compared to Set-A operation. Sponge iron was proved to be more effective in reducing the pollutants than manganese ore. Methanol blended gasoline reduced pollutants effectively in comparison with gasohol operation in both versions of the engine.

6. ACKNOWLEDGEMENTS

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

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