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Comparative Studies on Emissions of Four Stroke Copper Coated Spark Ignition Engine with Catalytic Converter with Different Catalysts with Gasohol

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Abstract – *Experiments were carried out to study the exhaust emissions 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 different catalysts of sponge iron and manganese ore with different test fuels of pure gasoline and gasohol (80% gasoline and 20% ethanol by volume) and compared with conventional engine (CE) with pure gasoline operation. Exhaust emissions of carbon monoxide (CO) and un-burnt hydro carbon (UBHC) were varied with different values of brake mean effective pressure (BMEP), speed, compression ratio with different operating conditions of catalytic converter with different catalyst. Aldehyde emissions were measured at peak load operation. CO and UBHC) were measured with Netel Chromatograph CO/UBHC analyzer. The engine was provided with catalytic converter with sponge iron and manganese ore as catalysts. There was provision for injection of air into the catalytic converter. The performance of the catalyst was compared with one over the other. Gasohol operation on CCE decreased exhaust emissions effectively in comparison with pure gasoline operation on CE. Catalytic converter with air injection significantly reduced pollutants with different test fuels on both configurations of the engine.*

Keywords – Catalytic converter, CCE, CE, exhaust emissions, gasohol, and SI engine.

1. INTRODUCTION

The civilization of a particular country depends on number of automotive vehicles being used by the public of the country. 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 and alternate fuel research. Alcohols are probable candidates as alternate fuels for SI engines, as their properties are compatible close to gasoline fuels. That too their octane ratings are 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]-[7]. Inhaling of these pollutants cause severe headache, vomiting sensation, loss of hemoglobin in the blood, respiratory problems etc, Such pollutants also cause detrimental effects [7] 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 exhaust emissions from the engine depends [3] on driving engine condition, driving methodology, road layout, traffic density, etc, If the engine is run with alcohol, aldehydes are to be checked. These aldehydes are carcinogenic in nature. Control of aldehyde emissions was not sufficiently reported in literature. Hence control of these emissions is immediate and an urgent task. There are many methods to control exhaust emissions from the engine, out of which engine modification [8]-[12] and provision of catalytic converter [13]-[20] to the engine are simple techniques. Copper is coated on piston crown and inner side of cylinder head because copper coating improves pre-flame reactions and hence combustion as copper is a good conductor of heat. With the provision of the catalytic converter to the engine, the reduction of CO and UBHC depends on mass of the catalyst, void ratio (defined as ratio of the volume of the catalyst to the volume of catalytic chamber), temperature of the catalyst, air flow rate, and speed and compression ratio of the engine. Alcohols [21]-[23] are blended with gasoline and used in CE and CCE [24]-[27] so as to improve the performance of the engine. However, no systematic studies were made on control of exhaust emissions from copper coated engine with the use of gasoline blended with ethanol with varied parameters of the engine and catalytic converter.

The present paper reported the performance evaluation of CCE, with different test fuels of pure gasoline and gasohol (gasoline 80% and methanol 20% by volume) with varied speed, compression ratio and compared with CE with pure gasoline operation. The exhaust emissions of carbon monoxide (CO), un-burnt hydro carbons (UBHC) and aldehydes were controlled by catalytic converter with different catalysts of sponge

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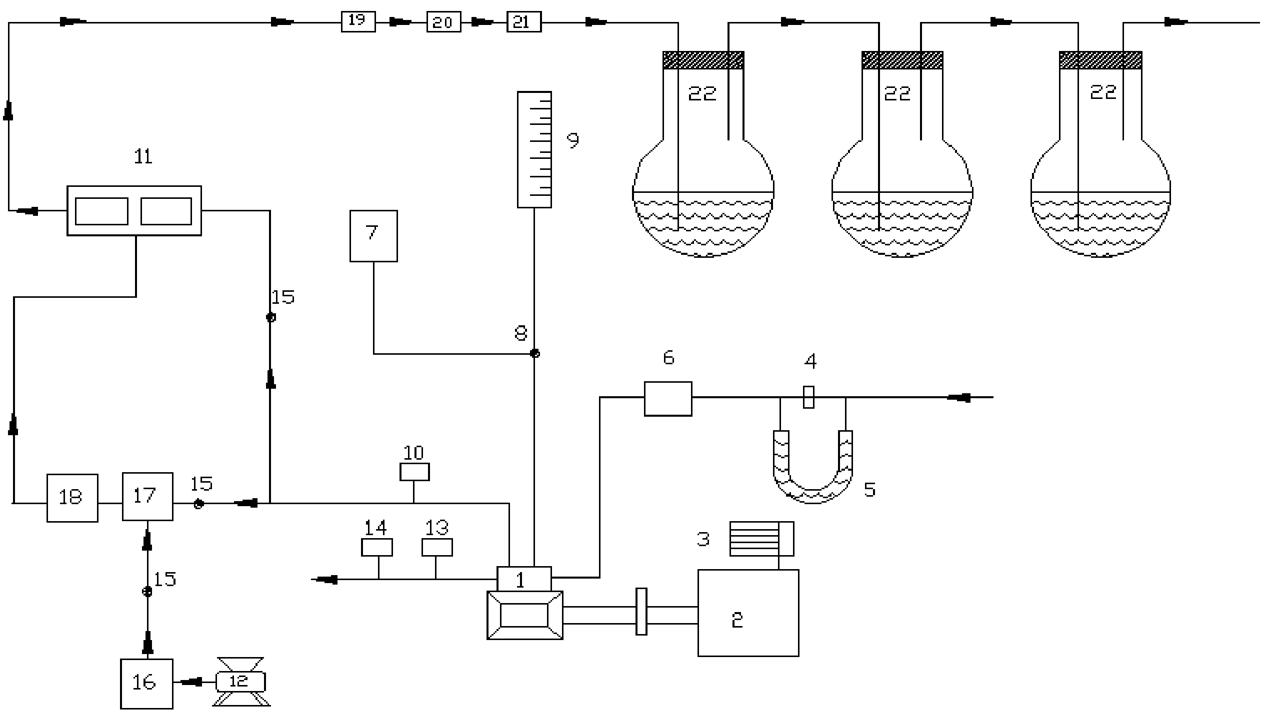
iron and manganese ore and the performance of the catalyst was compared with one over the other.

2. METHODOLOGY

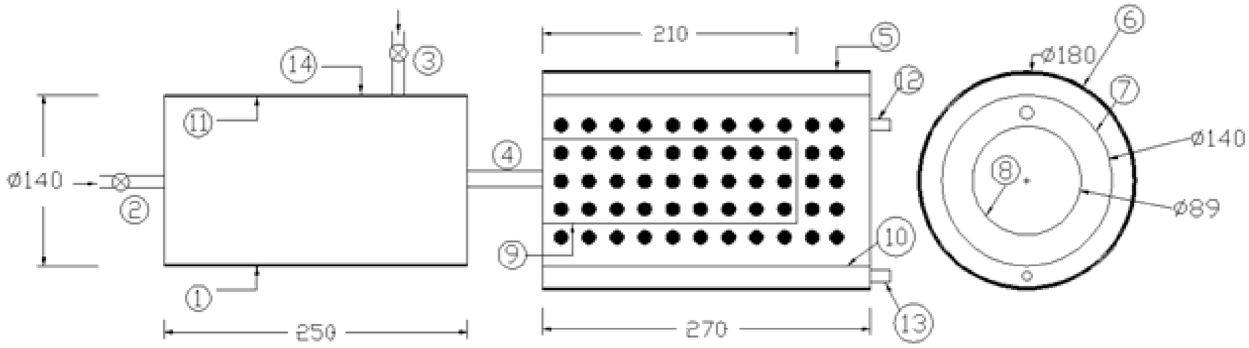
Figure 1 shows experimental set-up used for investigations on CCE with alcohol blended gasoline. A four- stroke, single-cylinder, water-cooled, SI engine (brake power 2.2 kW, at the speed 3000 rpm) was coupled to an eddy current dynamometer for measuring its brake power. Compression ratio of engine was varied (3-9) with change of clearance volume by adjustment of cylinder head, threaded to cylinder of the engine. Engine speeds were varied from 2000 to 3000 rpm. Exhaust gas temperature was measured with iron-constantan thermocouples. In catalytic coated engine, piston crown and inner surface of cylinder head were coated with copper by plasma spraying. A bond coating of Ni-Co-Cr alloy was applied (thickness, 100 μ) using a 80 kW METCO (Company trade name) plasma spray gun. Over bond coating, copper (89.5%), aluminum (9.5%) and iron (1.0%) were coated (thickness 300 μ). The coating has very high bond strength and does not wear off even after 50 h of operation [9]. CO and UBHC emissions in engine exhaust were measured with Netel Chromatograph analyzer. DNPH method (dinitrophenyl hydrazine) [15] was employed for measuring aldehydes in the experimentation. The exhaust of the engine was bubbled through 2, 4 DNPH solution. The hydrazones formed were extracted into chloroform and were analyzed by employing high performance liquid chromatography (HPLC) to find the percentage concentration of formaldehyde and acetaldehyde in the exhaust of the engine.

A catalytic converter [13] (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 does not increase. Experiments were 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. The accuracy of the instrumentation used in the experimentation is 0.1%. The test fuels used in the experimentation were pure gasoline and gasohol. The various configurations used in the experimentations were CE and CCE. The various catalyst used in the experimentation were sponge iron (S) and manganese ore (M).



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 18. Catalyst chamber 19. Filter, 20. Rotometer, 21. Heater, 22. Round bottom flasks containing DNPH solution

Fig. 1. 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 the compressor, 4. Outlet for air chamber, 5. Catalytic chamber, 6. Outer cylinder, 7. Intermediate-cylinder, 8. Inner-cylinder, 9.Inner sheet, 10.Intermediate sheet, 11. Outer sheet, 12. Outlet for exhaust gases, 13. Provision to deposit the catalyst, and, 14. Insulation.

Fig. 2. Details of the catalytic converter.

3. RESULTS AND DISCUSSION

From Figure 3, it is noticed that as compression ratio decreased, CO emissions decreased in both versions of the engine with test fuels. This was due to increase of exhaust gas temperatures with decrease of compression ratios leading to oxidation of CO emissions in the exhaust pipe producing CO_2 emissions. Similar trends were reported [9] earlier.

Curves from Figure 4 indicates that methanol blended gasoline decreased CO emissions at all loads when compared to pure gasoline operation on both versions of the engine, as fuel-cracking reactions were eliminated with ethanol. The combustion of alcohol produced more water vapor than free carbon atoms as ethanol has lower C/H ratio of 0.33 against 0.44 of gasoline. Ethanol has oxygen in its structure and hence its blends have lower stoichiometric air requirements compared to gasoline. Therefore more oxygen that was available for combustion with the blends of ethanol and gasoline, lead to reduction of CO emissions. Ethanol dissociated in the combustion chamber of the engine forming hydrogen, which helped the fuel-air mixture to burn quickly and thus increases combustion velocity, which brought about complete combustion of carbon present in the fuel to CO_2 and also CO to CO_2 thus made 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 pure gasoline operation on CCE [9].

From Figure 5 it is observed that as speed increased, un-burnt hydro carbon emissions (UBHC) decreased in both versions of the engine with test fuels. As speed increased turbulence of combustion increased. Hence catalytic activity of CCE increased as temperature increased, leading to reduction of fuel deposits and crevice deposits. It is worth to note that substantial oxidation of the hydrocarbon which escapes the primary combustion process can occur during expansion and exhaust depending upon the temperature and oxygen concentration time histories of HC as they mix with bulk gases. With gasohol, more oxygen is available as oxygen is inherently present in the fuel composition, and temperature increased with the increase of speed and turbulence, causing reduction of UBHC emissions.

Figure 6 indicates that UBHC emissions followed the similar trend as CO emissions in CCE and CE with both test fuels. One of the sources of UBHC is due to bulk quenching of the flame. Such conditions arise during transient engine operation when air-fuel ratio, spark timing and fraction of the exhaust recycled for emission control may not be properly matched. Since spark plug timing is maintained constant, there is no exhaust recirculation and hence UBHC emissions depend on air fuel ratio. Air fuel ratio increased up to 80% of the peak load operation for both test fuels with different versions of the engine. Hence UBHC emissions decreased during this load and beyond this load, they increased. Thermal efficiency was found to be higher at 80% of the peak load with test fuels with different configurations of the engine. This was because of increase of fuel conversion of efficiency and reduction fuel deposits and fuel concentration at crevices. CCE decreased UBHC emissions considerably when compared with CE. This was because of improved combustion and reduction of crevice deposits.

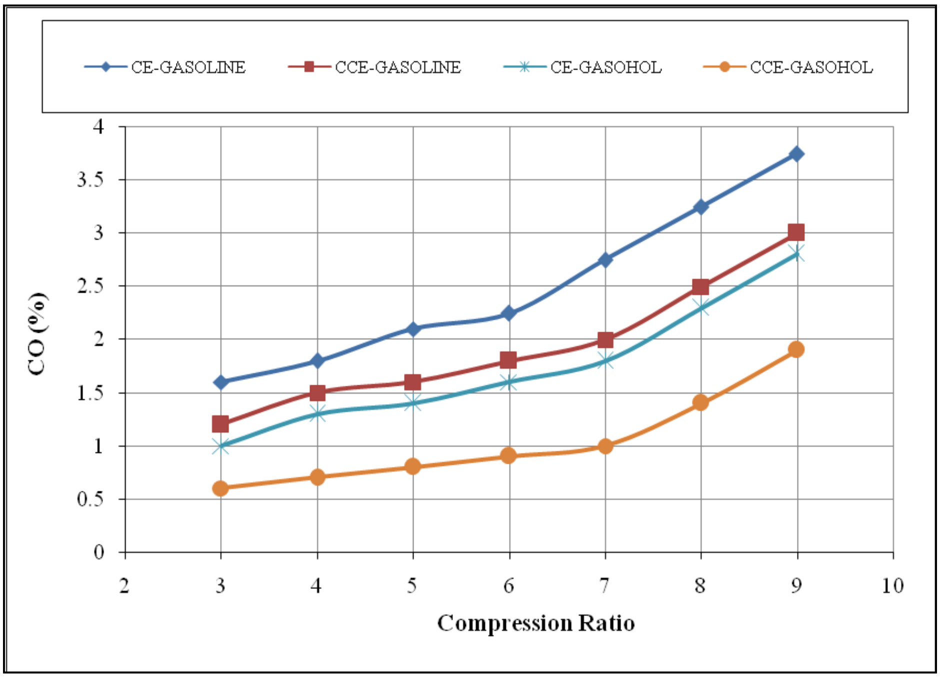


Fig. 3. Variation of CO emissions with compression ratio in both versions of the engine at a speed of 3000 rpm with test fuels.

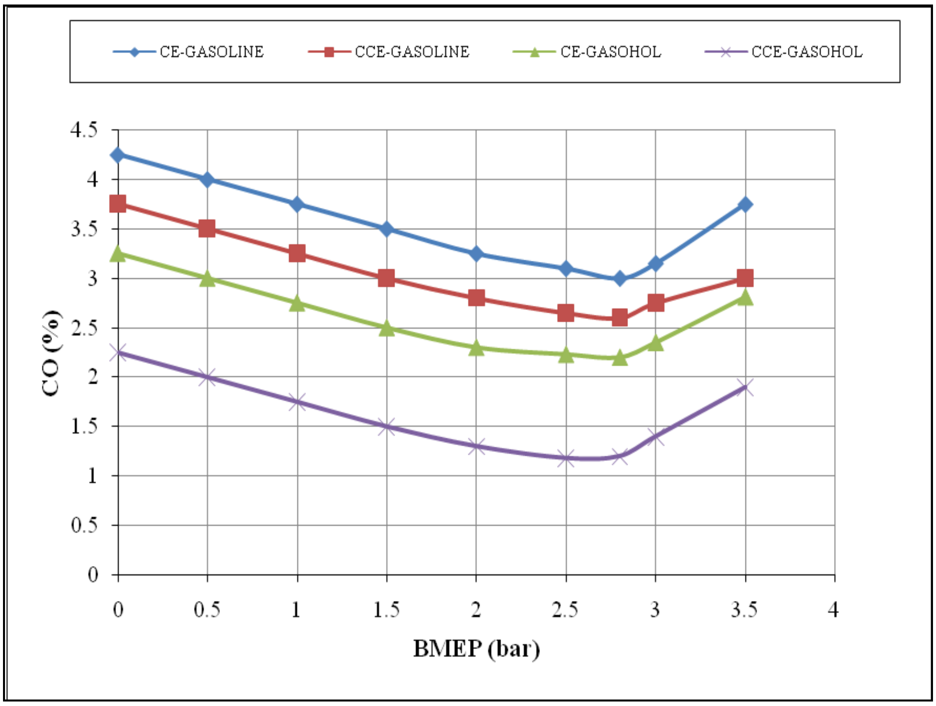


Fig. 4. Variation of CO emissions with BMEP of the engine in both versions of the engine with pure gasoline and gasohol at a speed of 3000 rpm and compression ratio of 9:1.

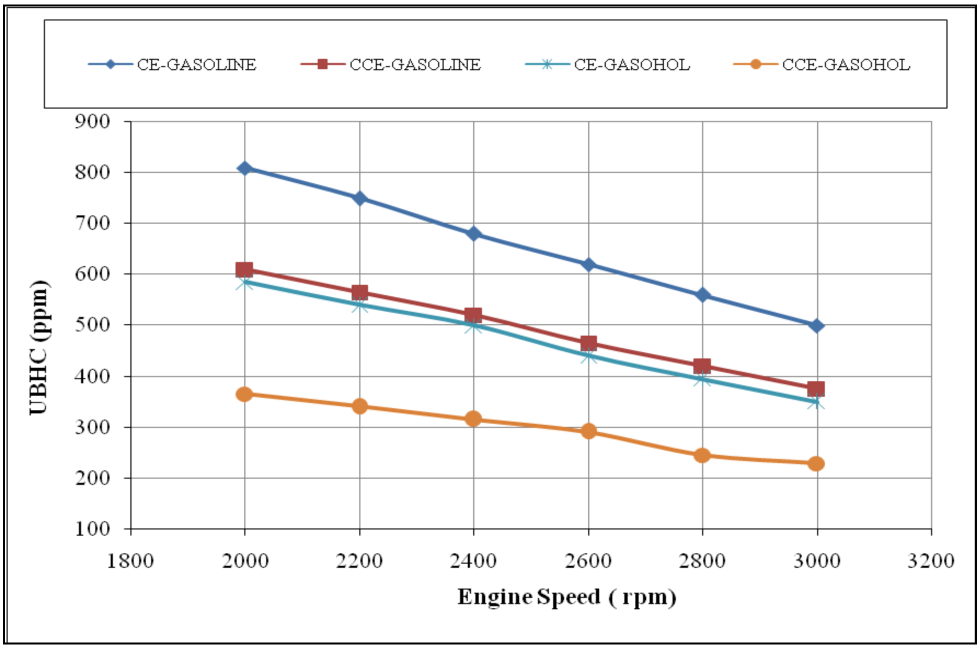


Fig. 5. Variation of UBHC emissions with speed of the engine in both versions of the engine with test fuels at a speed of 3000 rpm and compression ratio of 9:1.

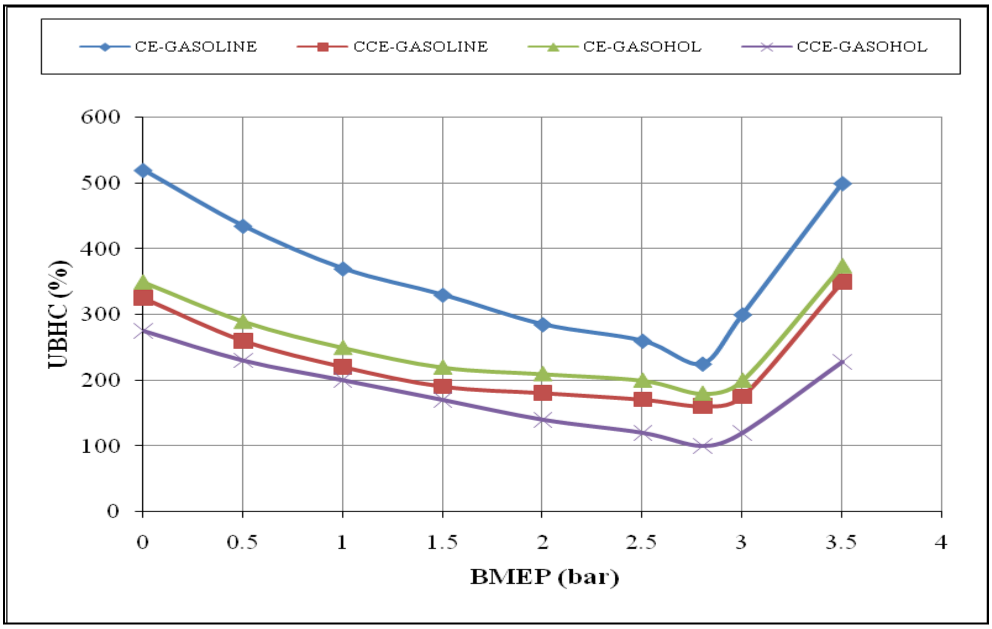


Fig. 6. Variation of UBHC emissions with BMEP of the engine in both versions of the engine with pure gasoline and gasohol at a speed of 3000 rpm and compression ratio of 9:1.

4. CATALYTIC CONVERTER

From Table 1, it is observed 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 ethanol 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 gasohol, turbulence and catalytic activity decreases 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. This was because of increase oxidation reaction leading to reduce emissions. However, gasohol increased aldehyde emissions considerably in comparison with pure gasoline operation. But CCE decreased aldehyde emissions in comparison with CE with gasohol. This was due to improved combustion so that intermediate compounds will not be formed.

Table 1. Data of exhaust emissions in four-stroke SI engine with different test fuels at different operating conditions of catalytic converter.

Emissions	Set	Pure Gasoline Operation				Gasohol Operation			
		CE		CCE		CE		CCE	
		S	M	S	M	S	M	S	M
CO (%)	Set-A	3.75	3.75	3.0	3.0	2.81	2.81	1.9	1.9
	Set-B	2.25	2.79	1.8	2.22	1.54	2.16	1.4	1.5
	Set-C	1.5	1.86	1.2	1.51	0.98	1.44	0.7	1.0
UBHC (ppm)	Set-A	500	500	375	375	350	350	228	228
	Set-B	300	360	206	265	165	270	130	197
	Set-C	200	240	105	145	122	180	80	131
Formaldehyde (% Concentration)	Set-A	6.5	6.5	4.5	4.5	12	12	9.0	9.0
	Set-B	4.5	4.9	2.5	2.9	5.6	6.1	5.1	5.6
	Set-C	2.5	2.9	1.5	1.9	4.8	5.4	3.4	3.8
Acetaldehyde (% Concentration)	Set-A	5.5	5.5	3.5	3.5	10	10	6.6	6.6
	Set-B	3.5	4.0	2.5	2.7	4.7	5.2	3.4	3.9
	Set-C	1.5	1.9	1.0	0.95	3.7	4.1	2.3	2.7

S= Sponge iron, M= Manganese ore, Set-A= without catalytic converter and without air injection
Set- B= with catalytic converter and without air injection.
Set- C= with catalytic converter and with air injection, CE= Conventional engine, CCE= Copper coated engine.

5. CONCLUSIONS

CO emissions increased marginally with increase of compression ratio and they were found to be lower at 80% of the peak load operation with test fuels and with different versions of the engine. CO and UBHC emissions decreased with increase of speed of the engine. These emissions decreased up to 80% of the peak load operation and beyond this load they increased in both versions of the engine with test fuels. CCE with gasohol decreased CO and UBHC emissions nearly by 50% in comparison with pure gasoline operation on CE. CCE improved combustion and decreased exhaust emissions effectively in comparison with CE with test fuels. Set-B operation of the catalytic converter decreased the pollutants by 45%, while Set- C by 60%. Sponge iron (S) was found to be more effective in reducing exhaust emissions in comparison with manganese ore (M).

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