Comparative Studies on Exhaust Emissions from Two Stroke Copper Coated Spark Ignition Engine with Alcohol Blended Gasoline with Catalytic Converter

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Abstract: *Experiments were conducted to control the exhaust emissions from single cylinder, two stroke, spark ignition (SI) engine, with alcohol blended gasoline (80% gasoline, 20% methanol, 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 and Manganese ore as catalysts and compared with conventional SI engine (CE) with pure gasoline operation. Aldehydes were measured by wet chemical method. Exhaust emissions of CO and UBHC were evaluated at different values of brake effective pressure, while aldehydes were measured at full load operation of the engine. A Netel Chromatograph 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. Catalytic converter with air injection significantly reduced pollutants with test fuels on both configurations of the engine. The catalyst, sponge iron reduced the pollutants effectively with both test fuels in both versions of the engine.*

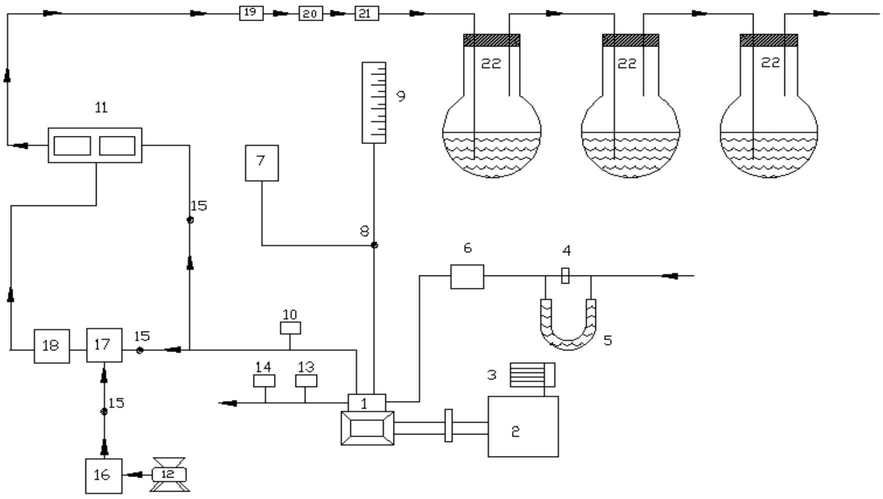
Keywords: *S.I. Engine, CE, copper coated combustion chamber, Exhaust Emissions, CO, UBHC, Aldehydes, Catalytic converter, Sponge iron, Manganese ore, Air injection*

1. INTRODUCTION

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] 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 [8] 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 [8-11] 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.

2. Materials and Methods

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].

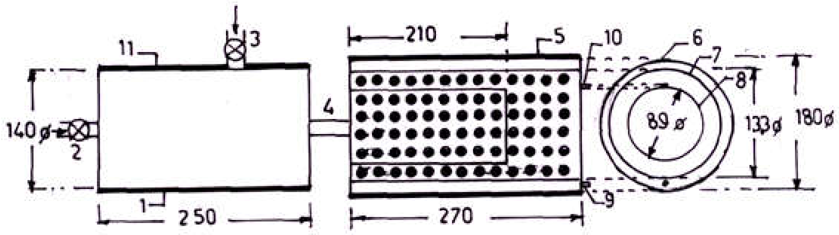


1. Engine, 2.Eddy current dynamometer, 3. Loading arrangement, 4. Orifice meter, 5. U-tube water monometer, 6. Air box, 7. Fuel tank, 8. Three-way valve, 9. Burette, 10. Exhaust gas temperature indicator, 11 CO analyzer, 12. Air compressor, 13. Outlet jacket water temperature indicator, 14. Outlet jacket water flow meter, 15. Directional valve, 16. Rotometer, 17. Air chamber and 18. Catalyst chamber 19. Filter, 20. Rotometer, 21. Heater, 22. Round bottom flasks containing DNPH solution

Figure 1. Schematic Diagram of Experimental set up

Figure.1 shows schematic diagram for experimental set-up used for investigations. A four- stroke, single-cylinder, water-cooled, SI engine (brake power 2.2 kW, rated speed 3000 A rpm) was coupled to an eddy current dynamometer for measuring brake power. Compression ratio of engine was varied (3-7) 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 was measured with burette method, while air consumption was measured with air-box method. The bore of the cylinder was 70 mm while stroke of the piston was 66 mm. The engine oil was provided with a pressure feed system. No temperature control was incorporated, for measuring the lube oil temperature. Recommended spark ignition timing was 25^{o}aTDC. CO and UBHC emissions in engine exhaust were measured with Netel Chromatograph analyzer. CO and UBHC emissions in engine exhaust were measured with Netel Chromatograph analyzer.

A catalytic converter [6] (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.



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

Figure 2. Details of Catalytic Converter

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.

3. Results and Discussion

The data of CO emissions {magnitude and the % deviation over the base condition (base engine-base fuel-set-A – SPI catalyst)} from the base engine and catalytic coated engine using experimental fuels under various sets of catalytic converter with SPI/Mn ore catalyst was presented in the Table-1.

Table-1 indicated that, methyl alcohol blend reduced the CO emissions with the use of catalyst and that with air injection in to the catalytic converter, CO emissions were decreased further. The catalyst temperature and rate of air flow were maintained at 30^0C and 120 lit/hr respectively. Methyl alcohol blend improved combustion because of which CO emissions reduced in both CE and CCE.

CCE was more effective in reducing the pollutants in comparison with the base engine with both catalysts, as good combustion is achieved due to turbulence with copper coating. Air injection further reduced the pollutants due to oxidation reactions in both the engine versions. SPI catalyst was found to be more effective in reducing the CO emissions in comparison with Mn ore for both engine versions using experimental fuels.

Table 1. Data of CO Emissions (%) at Full Load Operation and the % Deviation over Base Condition Operation

Engine version→		Base engine				Catalytic coated engine			
Fuel used→		Base fuel		Methyl alcohol blend		Base fuel		Methyl alcohol blend	
Catalyst→ / Conditions↓		SPI	Mn ore	SPI	Mn ore	SPI	Mn ore	SPI	Mn ore
Set-A	Magnitude	5	5	3	3	4	4	2.4	2.4
	% deviation	--	--	- 40%	- 40%	-20%	-20%	-52%	- 52 %
Set-B	Magnitude	3	4	1.8	2.1	2.4	3.2	1.44	1.92
	% deviation	-40 %	-20 %	- 64 %	- 58 %	-52%	- 36%	-71.2%	-61.6%
Set-C	Magnitude	2	3	1.2	1.5	1.6	2.4	0.96	1.44
	% deviation	-60 %	-40 %	- 76 %	- 70 %	-68%	-52 %	-80.8%	-71.2%

The data of UBHC emissions {magnitude and the % deviation over the base condition (base engine-base fuel-set-A – SPI catalyst)} from the base engine and catalytic coated engine using experimental fuels under various sets of catalytic converter with SPI/Mn ore catalyst was presented in the Table-2.

Table 2. Data of UBHC Emissions (ppm) at Full Load Operation and the % Deviation over Base Condition Operation

Engine version→		Base engine				Catalytic coated engine			
Fuel used→		Base fuel		Methyl alcohol blend		Base fuel		Methyl alcohol blend	
Catalyst→ / Conditions↓		SPI	Mn ore	SPI	Mn ore	SPI	Mn ore	SPI	Mn ore
Set-A	Magnitude	750	750	525	525	600	600	420	420
	% deviation	--	--	- 30 %	- 30 %	-20 %	-20 %	- 44 %	- 44 %
Set-B	Magnitude	450	600	315	420	360	480	252	335
	% deviation	-40 %	-20 %	- 58 %	- 44 %	-52 %	-36 %	-66.4 %	-55.3 %
Set-C	Magnitude	300	450	210	315	240	360	168	250
	% deviation	-60 %	-40 %	- 72 %	- 58 %	-68 %	-52 %	-77.6 %	-66.6 %

It was seen in the Table-2 that, UBHC emissions followed the similar trends that were observed with CO emissions. However, UBHC emissions depends on quenching area (accumulation of fuel in crevices), while CO emissions depend on incomplete combustion. There may be quantitative difference between these two, but qualitatively their behavior is the same. Methyl alcohol blend was observed to be more suitable in reducing the pollutants rather than the base fuel. CCE is more effective in reducing the pollutants in comparison with CE with both catalysts, as improved combustion is achieved due to turbulence with copper coating. The exhaust emissions were observed to be decreased with the catalytic converter and were further decreased with the injection of air in to the catalytic converter. This was because of the completion of oxidation reaction with the catalyst which results in the formation of CO_2 instead of CO. Sponge iron catalyst was found to be more effective in the decrease of UBHC emissions over Mn ore for both engine configurations using experimental fuels.

Table-3 shows the data of Formaldehyde and Acetaldehyde emissions (magnitude and % variation over CE with the same fuel).

From the Table-3, it was observed that, with the provision of catalytic converter coupled with injection of air, both the aldehyde emissions were decreased. CCE decreased both aldehyde emissions in comparison with the base engine using the experimental fuels. This was due to improved combustion so that there was no formation of incomplete combustion products. SPI catalyst effectively reduced both the aldehyde emissions over Mn ore for both engine configurations using experimental fuels. Hence catalytically activated engine with SPI catalyst along with air injection in to catalytic converter was more suitable in reducing both the aldehyde emissions when compared with base engine.

Table 3. Data of Aldehyde Emissions (% Concentration) at Full Load Operation in the Base Engine and Catalytic Coated Engine

Aldehyde emissions	Catalyst	Test fuel→	Base fuel			Methyl alcohol blend		
		Engine version→ / Condition of catalytic converter↓	Base engine	CCE	% variation over the base engine	Base engine	CCE	% variation over the base engine
Formaldehyde emissions	Sponge iron	Set-A	9.1	6.8	- 25.2 %	23.6	13.6	- 42.3 %
		Set-B	6.3	4.1	- 34.9 %	10.8	10.2	- 5.5 %
		Set-C	3.5	3.2	- 8.6 %	8	5.5	- 31.3 %
	Mn ore	Set-A	9.1	6.8	- 25.2 %	23.6	13.6	- 42.3 %
		Set-B	8.2	5.9	- 28 %	12.6	12	- 4.7 %
		Set-C	5.5	5	- 9.1 %	10.1	7.2	- 28.7 %
Acetaldehyde emissions	Sponge iron	Set-A	7.7	4.9	- 36.3 %	12.3	9.3	- 24.3 %
		Set-B	4.9	3.5	- 28.5 %	7.7	6.5	- 15.6 %
		Set-C	2.1	1.4	- 33.3 %	3.9	3.1	- 20.5 %
	Mn ore	Set-A	7.7	4.9	- 36.3 %	12.3	9.3	- 24.3 %
		Set-B	7.2	5.3	- 26.3 %	9.5	8.5	- 10.5 %
		Set-C	4.3	3.1	- 27.9 %	5.6	4.8	- 14.3 %

4. Conclusions

1. Methyl alcohol blend in the catalytic coated engine decreased CO emissions and UBHC emissions by 52% and 44% respectively when compared to the base engine using base fuel.
2. With base fuel, catalytic coated engine decreased formaldehyde emissions and acetaldehyde emissions by 25.3% and 36.4% respectively in comparison with CE.
3. Catalytic coated engine decreased formaldehyde emissions and acetaldehyde emissions by 42.4% and 24.4% respectively with methyl alcohol blend when compared to the base engine.
4. Catalytic coated engine with methyl alcohol blend and sponge iron catalyst decreased the CO emissions and UBHC emissions by 71% and 67% respectively without air injection, while the emissions were decreased by 81% and 78% respectively with air injection in comparison with the base engine.
5. With methyl alcohol blend and manganese ore catalyst, catalytic coated engine decreased the CO emissions and UBHC emissions by 62% and 56% respectively without air injection, while they were decreased by 72% and 67% respectively with air injection, in comparison with the base engine operation.
6. Formaldehyde emissions and acetaldehyde emissions, from the base engine and catalytic coated engine using both experimental fuels, were decreased with injection of air in to catalytic converter.
7. Sponge iron catalyst was more effective in reducing exhaust emissions in comparison with manganese ore for both configurations of the engine using experimental fuels.

Acknowledgements

The author thanks the authorities of Chaitanya Bharathi Institute of Technology (CBIT), Hyderabad, for facilities provided. The author sincerely thanks the authorities of M/s Sai Surface Coating (P) Limited, Patancheru, Hyderabad for extending the cooperation in coating the components of the SI engine.

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