Control of Exhaust Emissions from Two Stroke SI Engine having Copper Coated Piston with Methanol Blended Gasoline with Catalytic Converter

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***Abstract*—** Experiments were conducted to evaluate and control the exhaust emissions from two stroke single cylinder, spark ignition (SI) engine, with alcohol blended gasoline (80% gasoline, 20% methanol, by volume) having copper coated engine [CCE, copper-(thickness, 300 μ) coated on piston crown] provided with catalytic converter with sponge iron and manganese ore as as catalysts and compared with conventional SI engine (CE) with pure gasoline operation. The exhaust emissions of carbon monoxide (CO) and unburnt hydrocarbons (UBHC) were determined at different values of Brake Mean Effective Pressure (BMEP) with Netel Chromatograph CO/UBHC analyzer. Aldehyde levels were determined by Dinitrophenyl Hydrazine (DNPH) method. Copper coated combustion chamber with alcohol blended gasoline with catalytic converter using sponge iron catalyst with air injection significantly reduced the pollutants in comparison with CE with pure gasoline operation. .

Keywords- *copper coated piston, methanol blend*, *catalytic converter, carbon monoxide, unburnt hydrocarbons, aldehydes*

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I. INTRODUCTION

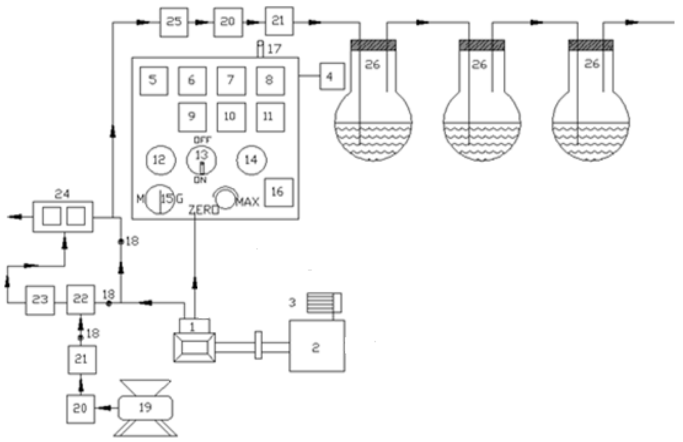
The paper is divided into i) Introduction, ii) Materials and Methods, iii) Results and Discussions, iv) Conclusions, Research Findings, Future scope of work followed by References.

Two-stroke engine develops more power than four-stroke engine, yet it faces criticism, as it emits higher pollution levels. Gasoline fuels can be blended with alcohols in SI engines, because of their compatible properties with that of gasoline fuels. The major emissions from SI engines when run with alcohols, are CO and UBHC, besides aldehydes(formaldehydes and acetaldehydes). As the exhaust emissions of CO (%), UBHC (ppm) and aldehydes (% concentration) cause harmful health hazards on human beings and on environment, necessary steps are to be taken in the form of changing the fuel composition or engine design modification or both, to decrease them. A simple technique to decrease the pollutants from the engine is coupling catalytic converter to the exhaust pipe of engine. CO is formed due to incomplete combustion. CO is formed when excess fuel is present and little oxygen is available. UBHC is formed due to 'quenching effect'. The fuel will settle in the crevices of the piston and on the inner walls of the combustion chamber, which will come out during the exhaust stroke in the form of UBHC. Aldehydes (formaldehydes and acetaldehydes), which are carcinogenic in nature, are formed as intermediate compounds in the combustion reactions, when the engine is run with alcohols. Aldehydes are measured with DNPH method. Yasar *et al.* [1] experimentally investigated the effects of methyl alcohol or butyl alcohol blend on the exhaust emissions and noise level. The results showed that the concentrations of CO and NOx emissions were decreased depending on the higher alcohol contents. At higher engine load, a decrease in the HC content and an increase in the noise level were observed. Murali Krishna *et al.* [2] carried out investigations on control of CO in the exhaust of engine [3]. Manganese ore is used as catalyst in the converter. CCE reduces the CO emissions considerably at different operating conditions when compared with CE.

II. MATERIALS AND METHODS

This section deals with fabrication of copper coated engine, description of experimental set up and definition of used values. In the copper coated engine, by flame spraying technique, a high thermal conductive catalytic material like copper was coated on the top surface of piston crown. For 100μ thickness, nickel-cobalt-chromium bond coating was sprayed. On this coating, for another 300μ thickness, an alloy of copper (89.5%), aluminium (9.5%) and iron (1%) was coated with a METCO (Trade name of the company) flame spray gun. The bond strength of the coating was so high that it does not wear off even after operating it for 50 hrs continuously [4, 5].

Fig.1 shows the schematic diagram of the experimental set up that was employed to analyze the exhaust emissions.

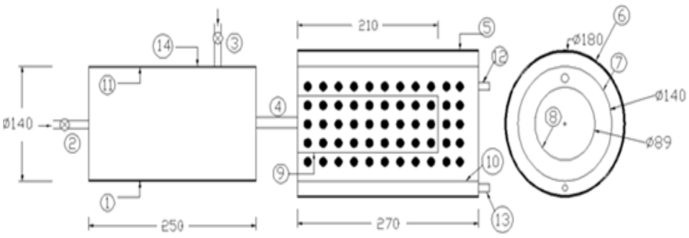


1.Engine,2.Electrical swinging field dynamometer, 3. Loading arrangement, 4.Fuel tank, 5.Torque indicator/controller sensor, 6. Fuel rate indicator sensor, 7. Hot wire gas flow indicator, 8. Multi- channel temperature indicator, 9. Speed indicator, 10. Air flow indicator, 11. Exhaust gas temperature 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,

Figure-1 Schematic diagram of the experimental set up

Plate-1 shows the photographic view of copper coated piston.

Plate-1 Photographic view of copper coated piston



Note: All dimensions are in mm

1. Air chamber, 2. Inlet for air chamber from engine, 3. Inlet for air chamber from 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 Catalytic converter

An air-cooled single-cylinder 2.2 kW BP two-stroke SI engine with a rated speed of 3000 rpm. CO and UBHC emissions in engine exhaust were measured with Netel Chromatograph CO/UBHC analyzer. Aldehyde emissions (formaldehydes and acetaldehydes) are measured with wet chemical (DNPH) method [6, 7, 8]. A catalytic converter [9] (Figure.2) is fitted to exhaust pipe of engine [10]. 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.

III. RESULTS AND DISCUSSION

This section deals with i). variation of CO emissions with BMEP, ii) variation of UBHC emissions with BMEP, and iii) data of Aldehyde emissions (Formaldehydes and Acetaldehydes)

A. Exhaust Emissions

Provision of catalytic converter and different operating conditions of catalytic converter are

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 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 (Sponge Iron) and Mn (Manganese) ore catalyst was presented in the Table-I and Table-II.

TABLE I. DATA OF CO EMISSIONS (%) AT FULL LOAD OPERATION

Engine version→	**CE**				**CCE**			
Fuel used→	*Pure gasoline*		*Methanol blended gasoline*		*Pure gasoline*		*Methanol blended gasoline*	
Catalyst→ / **Conditions ↓**	*Sponge Iron*	*Mn ore*	*Sponge Iron*	*Mn ore*	*Sponge Iron*	*Mn ore*	*Sponge Iron*	*Mn ore*
Set-A	5.9	5.9	3.9	3.9	4.9	4.9	3.3	3.3
Set-B	3.6	4.7	2.3	2.7	2.9	3.9	1.98	2.64
Set-C	2.3	3.5	1.5	1.9	1.9	2.9	1.32	1.98

TABLE II. % DEVIATION OF CO EMISSIONS (%) OVER BASE CONDITION AT FULL LOAD OPERATION

Engine version→	**CE**				**CCE**			
Fuel used→	*Pure gasoline*		*Methanol blended gasoline*		*Pure gasoline*		*Methanol blended gasoline*	
Catalyst→ / **Conditions ↓**	*Sponge Iron*	*Mn ore*	*Sponge Iron*	*Mn ore*	*Sponge Iron*	*Mn ore*	*Sponge Iron*	*Mn ore*
Set-A	---	---	- 34%	- 34%	- 17%	- 17%	- 44%	- 44%
Set-B	- 39%	- 20%	- 61%	- 54%	- 51%	- 34%	- 66%	- 55%
Set-C	- 61%	- 41%	- 74%	- 68%	- 68%	- 51%	- 78%	- 66%

Table-I and Table-II 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.

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 (Sponge Iron) and Mn (Manganese) ore catalyst was presented in the Table-III and Table-IV.

It was seen in the Table-III 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.

TABLE III. DATA OF UBHC EMISSIONS (PPM) AT FULL LOAD OPERATION

Engine version→	**CE**				**CCE**			
Fuel used→	***Pure gasoline***		***Methanol blended gasoline***		***Pure gasoline***		***Methanol blended gasoline***	
Catalyst→ / **Conditions ↓**	***Sponge Iron***	***Mn or***	***Sponge Iron***	***Mn ore***	***Sponge Iron***	***Mn or***	***Sponge Iron***	***Mn or***
Set-A	770	770	550	550	630	630	440	440
Set-B	462	616	330	440	378	504	264	352
Set-C	308	462	220	330	252	378	176	264

TABLE IV. % DEVIATION OF UBHC EMISSIONS (%) OVER BASE CONDITION AT FULL LOAD OPERATION

Engine version→	**CE**				**CCE**			
Fuel used→	***Pure gasoline***		***Methanol blended gasoline***		***Pure gasoline***		***Methanol blended gasoline***	
Catalyst→ / **Conditions**	***Sponge Iron***	***Mn or***	***Sponge Iron***	***Mn ore***	***Sponge Iron***	***Mn or***	***Sponge Iron***	***Mn or***
Set-A	---	---	- 29%	- 29%	- 18%	-18%	- 43%	-43%
Set-B	- 40%	-20%	- 57%	- 43%	- 51%	-35%	- 66%	-54%
Set-C	- 60%	-40%	- 71%	- 57%	- 67%	-51%	- 77%	-66%

Table-III and Table-IV indicated that, methyl alcohol blend reduced the UBHC emissions with the use of sponge iron catalyst and that with air injection in to the catalytic converter, UBHC emissions were decreased further.

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

From the Table-V and Table-VI 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. Sponge iron catalyst effectively reduced both the aldehyde emissions over Mn ore for both engine configurations using experimental fuels. Hence CCE with Sponge iron catalyst along with air injection in to catalytic converter was more suitable in reducing both the aldehyde emissions.

TABLE V. DATA OF FORMALDEHYDE EMISSIONS (% CONCENTRATION) AT FULL LOAD OPERATION

Catalyst	**Test fuel→**	**Base fuel**			**Methyl alcohol blend**		
	Engine version→ / **Condition ↓**	***CE***	***CCE***	***% variation over CE***	***CE***	***CCE***	***% variation over CE***
Sponge iron	Set-A	10.4	7.8	- 25 %	27.1	15.6	- 42.4 %
	Set-B	7.1	4.6	- 35 %	12.2	11.7	- 4.1 %
	Set-C	3.9	3.6	- 7.7 %	9.2	6.2	- 32.6 %
Mn ore	Set-A	10.4	7.8	- 25 %	27.1	15.6	- 42.4 %
	Set-B	9.4	6.7	- 28.7 %	14.4	13.7	- 4.9 %
	Set-C	6.2	5.7	- 8.1 %	11.8	8.1	- 31.3 %

TABLE VI. DATA OF FORMALDEHYDE EMISSIONS (% CONCENTRATION) AT FULL LOAD OPERATION

Catalyst	**Test fuel→**	**Base fuel**			**Methyl alcohol blend**		
	Engine version→ / **Condition ↓**	***CE***	***CCE***	***% variation over CE***	***CE***	***CCE***	***% variation over CE***
Sponge iron	Set-A	8.8	5.6	- 36 %	14.1	10.6	- 24.8 %
	Set-B	5.6	3.9	- 30.3 %	8.8	7.3	- 17 %
	Set-C	2.3	1.5	- 34.7 %	4.4	3.4	- 22.7 %
Mn ore	Set-A	8.8	5.6	- 36 %	14.1	10.6	- 24.8 %
	Set-B	8.1	6.1	- 24.6 %	10.8	9.6	- 11.1 %
	Set-C	6.2	5.7	- 8.1 %	11.8	8.1	- 31.3 %

IV. CONCLUSIONS

1. Catalytic coated engine with methyl alcohol blend and sponge iron catalyst decreased the CO emissions and UBHC emissions by 66% and 66% respectively without air injection, while the emissions were decreased by 78% and 77% respectively with air injection in comparison with the base engine.
2. With methyl alcohol blend and manganese ore catalyst, catalytic coated engine decreased the CO emissions and UBHC emissions by 55% and 54% respectively without air injection, while they were decreased by 66% and 66% respectively with air injection, in comparison with the base engine operation.
3. Formaldehyde emissions and acetaldehyde emissions, from the base engine and catalytic coated engine using

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both experimental fuels, were decreased with injection of air in to catalytic converter.

4. Sponge iron catalyst was more effective in reducing exhaust emissions in comparison with manganese ore for both configurations of the engine using experimental fuels.

A. Research Findings and Future Scope of Work

The control of exhaust emissions with copper coating on top surface of piston with catalytic converter employing catalysts was systematically investigated. Copper coating can be done in addition on the inner surface of cylinder head also to decrease the pollutants further

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