COMPARATIVE STUDIES ON CONTROL OF EMISSIONS OF TWO STROKE AND FOUR STROKE SPARK IGNITION ENGINES

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ABSTRACT

Alcohols are proved to be efficient fuels for petrol engine, as their octane rating are very high and that too, there are renewable in nature. The exhaust emissions of petrol engine cause human hazards, once they are inhaled in and also cause environmental effects like Greenhouse effect and acid rains. Hence control of these pollutants is an immediate step and an urgent task. Investigations were carried out to determine and control the exhaust emissions of carbon monoxide (CO) and un-burnt hydro carbons (UBHC) emissions of two stroke and four stroke of 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 sponge iron as catalyst with methanol blended gasoline (80% gasoline and 20% methanol by volume) and compared with conventional engine (CE) with neat gasoline operation. The engine was provided with catalytic converter with sponge iron as catalyst. There was provision for injection of air into the catalytic converter. CCE showed reduction of pollutants, when compared with CE with both test fuels. 4-Stroke engine decreased exhaust emissions effectively in comparison with 2-stroke engine with

both versions of the engine at same compression ratio. Catalytic converter with air injection significantly reduced pollutants with different test fuels on both configurations of the engine.

Keywords: Alternative fuels, Methanol, CE, CCE, Fuel Performance, Exhaust emissions and Catalytic converter.

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1. INTRODUCTION

In the context of fast depletion of fossil fuels, the search for alternative fuels has become pertinent. Alcohols are probable candidates as alternative fuels for spark ignition (SI) engines, as their properties are compatible close to gasoline fuels. If alcohols are blended in small quantities with gasoline fuels, no engine modification is necessary. These alcohols can be prepared from municipal waste.[1].

The major exhaust emissions from SI engine are carbon monoxide (CO) and un-burnt hydrocarbons (UBHC), formed due to incomplete combustion of fuel. Inhaling of these pollutants cause [1-6] severe headache, vomiting sensation, loss of hemoglobin in the blood, respiratory problems etc.,. Such pollutants also cause detrimental effects [6] 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 [2] on driving engine condition, driving methodology, road layout, traffic density, etc.,. Hence control of these emissions is immediate and an urgent task. There are many methods to improve the performance of the engine out of which engine modification [7-11] 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 and pre-flame reactions were improved with copper coating. Out of many methods available to control pollutants from SI engine, catalytic converter is effective [12-15] in reduction of pollutants in SI engine. The reduction of CO and UBHC depends on mass of the catalyst, void ratio, temperature of the catalyst, air flow rate, BMEP, speed and compression ratio of the engine, Engine performance improved [16-21] with change in fuel composition also. It was further improved [22-26] with simultaneous change of fuel composition and engine modification. Alcohols are blended with gasoline and used in copper coated engine so as to improve the performance of the engine. However, no systematic investigations were reported with the use of methanol blended gasoline in 2 stroke and 4 stroke copper coated engine with varied engine parameters.

The present paper reported the control of exhaust emissions of 2-stroke and 4-stroke CCE, with methanol blended gasoline at the same compression ratio. The exhaust emissions of CO, UBHC and aldehydes were controlled by catalytic converter with sponge iron as catalyst.

2. MATERIALS AND METHODS

Figure.1 consisted 4-stroke CCE with methanol blended gasoline, used in the experiment. 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. The bore of the engine was 70 mm while the stroke was 66 mm. Compression ratio of engine was varied (3-9) with change of clearance volume by adjustment of cylinder head, threaded to cylinder of the engine. However, compression ratio was maintained as 7.5:1, as the compression ratio of 2

stroke engine was also 7.5:1, as there should not be any effect of compression ratio on exhaust emissions of the engine. Engine speeds were varied from 2000 to 3000 rpm. Exhaust gas temperature was measured with iron- constantan thermocouples. Fuel consumption of engine was measured with burette method, while air consumption was measured with an air-box method.

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. Rotameter, 17. Air chamber and 18. Catalyst chamber 19. Filter, 20. Rotameter, 21. Heater, 22. Round bottom flasks containing DNPH solution

Figure 1 Experimental set up (4-Stroke Engine)

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. Rotameter, 21. Heater, 22. Air chamber, 23. Catalytic chamber, 24. CO/HC analyzer, 25. Filter, 26. Round bottom flasks containing DNPH solution,

Figure 2 Schematic diagram of the Experimental Set-up (2-Stroke)

The experimental setup contained 2-stroke CCE with methanol blended gasoline is shown in Figure 2. A two- stroke, single-cylinder, air -cooled, SI engine (brake power 2.2 kW at the speed of 3000 rpm) was coupled to a eddy current dynamometer for measuring its brake power. The bore and stroke of engine cylinder was 57 mm each. 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. Compression ratio and speed of 4-stroke engine was made equal (3000 rpm and 7.5:1) to that of 2-stroke engine in order to maintain same conditions for comparison purpose.

Fig.3 shows schematic diagram of catalytic converter.

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.

Figure 3 Details of Catalytic converter

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 (Trade name of the company) flame spray gun. The coating has very high bond strength and does not wear off even after 50 h of operation [7].

CO and UBHC emissions in engine exhaust were measured with Netel Chromatograph analyzer. DNPH method [27-29] was employed for measuring aldehydes in the experimentation. The exhaust of the engine was bubbled through 2,4 dinitrophenyl hydrazine (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 [12] (Figure .3) 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%.

3. RESULTS AND DISCUSSION

3.1 Exhaust Emissions

Figure. 4 shows variation of CO emissions with brake mean effective pressure (BMEP) of the engine for 2 stroke SI engine, at a compression ratio of 7.5:1 and speed 3000 rpm. Curves from

Fig.4.indicate that methanol blended gasoline operation decreased CO emissions at all loads when compared to neat gasoline operation on CCE and CE, as fuel-cracking reactions were eliminated with methanol. The combustion of alcohol produced more water vapor than free carbon atoms as methanol has lower C/H ratio of 0.33 against 0.44 of gasoline. Methanol 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 methanol and gasoline, lead to reduction of CO emissions. Methanol 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 Reference-10 with pure gasoline operation on CCE.

Figure 4 Variation of CO emissions with BMEP of the 2-Stroke

Figure.5 presents bar charts showing the variation of CO emissions at full load for 2 stroke and 4 stroke SI engine with different test fuels and with different configurations of the engine. From Fig.5, it is noticed that CO emissions were observed to be lower with 4 stroke engine in comparison with 2 stroke engine at peak load operation on both versions of the engine. This was due to incomplete combustion of fuel and lower thermal efficiency of 2 stroke engine. Complete fuel will not participate in combustion reactions causing increase of CO emissions with 2 stroke engine.

Figure 5 Bar charts showing the variation of CO emissions of at full load operation

Figure.6 presents bar charts showing the variation of UBHC emissions at full load for 2 stroke and 4 stroke SI engine with different test fuels and with different configurations of the engine. Figure. 6 indicates that 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.

Figure 6 Variation of UBHC emissions with BMEP of 2-Stroke engine

Figure.7. presents bar charts showing the variation of UBHC emissions at full load for 2 stroke and 4 stroke SI engine with different test fuels and with different configurations of the engine.

Figure 7 Bar charts showing the variation of UBHC emissions of at full load operation

From Figure.7, it is noticed that UBHC emissions at full load operation were observed to be less with 4-stroke engine in comparison with 2-stroke engine at peak load operation on both versions of the engine. This was due to increase of quenching effect with 2-stroke engine leading to expel out of the fresh fuel without participating in combustion reactions causing higher amount of UBHC.

3.2 Catalytic Converter

Table.1 presents data of exhaust emissions in 2 and 4-strokes engine. Catalytic converter reduced pollutants considerably with CE and CCE and air injection into catalytic converter further reduced pollutants. In presence of catalyst, pollutants get further oxidised to give less harmful emissions like CO₂. 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. 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 methanol blended gasoline coupled with catalytic activity decreased CO emissions in CCE. From 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 methanol blended gasoline along with turbulence with catalytic activity decreased deposits in CCE causing decrease of UBHC emissions. CO and UBHC emissions were observed to be higher with 2 stroke engine in comparison with 4 stroke engine with different versions of the engine with different test fuels at same compression ration and speed. 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. However, methanol blended gasoline increased aldehyde emissions considerably in comparison with pure gasoline operation. But CCE decreased aldehyde emissions in comparison with CE with both test fuels. This is due to improved combustion so that intermediate compounds will not be formed. 2-Stroke engine increased aldehyde emissions than 4 stroke engine as combustion reactions are incomplete with 2 stroke engine.

Table 1 Data of Exhaust Emissions in Four-stroke and Two-stroke SI engine with different test fuels at different operating conditions of catalytic converter

Emissions	Set	Pure Gasoline Operation				Methanol Blended Gasoline			
		CE		CCE		CE		CCE	
		2 S	4S	2S	4S	2S	4S	2S	4S
CO (%)	Set-A	4.3	3.8	3.4	2.9	2.8	2.3	2.0	1.5
	Set-B	2.58	2.1	2.04	1.8	1.7	1.1	1.3	0.8
	Set-C	1.2	0.9	1.0	0.8	0.7	0.6	0.6	0.5
UBHC (ppm)	Set-A	700	500	550	375	425	350	350	228
	Set-B	370	310	250	220	235	175	190	130
	Set-C	160	120	130	110	100	90	80	70
Formaldehyde (% Concentration)	Set-A	6.5	4.5	5.5	4.5	12	10	11	8
	Set-B	3.5	2.5	1.5	1.2	4.0	3.5	3.8	2.9
	Set-C	2.2	1.7	1.5	0.8	4.2	3.8	2.9	1.9
Acetaldehyde (% Concentration)	Set-A	8.5	7.0	6.0	5.0	15	12	10	9.0
	Set-B	5.5	4.0	4.5	3.0	9	7	8	6.0
	Set-C	4.0	3.0	3.3	2.1	8	6	7	5

4. CONCLUSIONS

In comparison with 2-stroke CCE engine with methanol blended gasoline operation, CO emissions decreased by 25% and UBHC emissions decreased by 29% with 4stroke CCE with methanol blended gasoline operation.

In comparison with 4-stroke CCE engine with methanol blended gasoline, CO emissions decreased by 53% and UBHC emissions decreased by 50% when compared with CE with pure gasoline operation. 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 40%, while Set- C by 60%.

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