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Control Of Pollution Levels of Four Stroke Spark Ignition Engine Fuelled With Methanol Blended Gasoline

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ABSTRACT

The exhaust emissions from spark ignition engine (SI) are carbon monoxide (CO), un-burnt hydro carbon (UBHC) and nitrogen oxide levels (NOx). These pollution levels cause health hazards if they are inhaled. Hence control of these pollutants from SI engine is an important and immediate task. In the context of depletion of fossil fuels, ever increase of pollution levels with fossil fuels and increase of economic burden on developing countries like India, the search for alternative fuels has become pertinent. Alcohols are important substitutes for gasoline engine as their properties are comparable to gasoline. Experiments are conducted to study pollution levels of CO, UBHC and NO_x with four–stroke, single– cylinder SI engine with methanol blended gasoline (20% methanol, 80% gasoline, by vol) having copper coated engine [CCE, copper-(thickness, 300 µ) coated on piston crown, inner side of liner and cylinder head] provided with catalytic converter with sponge iron as catalyst and compared with conventional SI engine (CE) with neat gasoline operation. NO_x levels were controlled by selective catalytic reduction (SCR) technique. CCE showed reduction in pollution levels when compared to CE with both test fuels. Catalytic converter with air injection significantly reduced pollutants with both test fuels on both configurations of the engine.

Keywords*:* CE, CCE, Pollutants, Catalytic converter, Selective catalytic Reduction Technique, Air injection.

1.INTRODUCTION

In the context of depletion of fossil fuels, ever increase of pollution levels with fossil fuels, ever increase of fuel prices in International Market causing economic burden on Govt of India, the search for alternative fuels has become pertinent. Alcohols are good substitutes for gasoline fuels, as their properties are comparable to gasoline, That too, their octane numbers are higher than that of gasoline fuels. Alcohol blended gasoline fuels were encouraged to use fuels in spark ignition engine to minimize the modification of the engine. [1–3]. The performance of SI engine was improved along with with reduction of pollutants by changing fuel composition, change of combustion chamber design and with provision of catalytic converter. Methanol blended gasoline [gasoline blended with methanol, 20%, by vol) improved engine performance and decreased pollution levels when compared with pure gasoline on CE [4–6]. Carbon monoxide (CO) and un-burnt hydrocarbons (UBHC) are major exhaust pollutants formed due to incomplete combustion of fuel, cause many human health disorders [7–12] NO_x is formed due to the availability of oxygen and temperature prevailing in combustion chamber. Such pollutants also cause detrimental effects on animal and plant life, besides environmental disorders. [10,12]. Engine modification with copper coating on piston crown and inner side of cylinder head improves engine performance as copper is better conductor of heat and good combustion is achieved with copper coating. [13–14]. Catalytic converter is effective in reduction of pollutants in SI engine. [15–16]. Pollution levels were studied with CCE with methanol blended gasoline in the present paper and compared with CE with neat gasoline operation. The control of NOx has been achieved by the improvements in the engine design and combustion chamber modification, such as retarded injection timing, turbo charging with inter cooling and exhaust gas recirculation. But most of these modifications resulted in increase of pollution by particulate emissions and deterioration of fuel economy [17]. However, the selective catalytic reduction technique was recognized as most effective in reduction of NO_x levels. The modified zeolites like lanthanum ion exchanged zeolites are cheaper and can reduce NOx over wide range of air-fuel ratios and temperatures.[18–22].

This paper presented control of pollution levels of CO and UBHC from SI engine with catalytic converter with sponge iron as catalyst, while nitrogen oxide levels were controlled by selective catalytic reduction technique and their performance is compared without catalytic converter. [17].

2.MATERIALS AND METHODS

Fig.1 shows experimental set-up used for investigations. A four- stroke, single-cylinder, water-cooled, SI engine (brake power 2.2 kW, rated speed 3000 rpm) is coupled to an eddy current dynamometer for measuring brake power. Compression ratio of engine is varied(3 -9) 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 is measured with burette method, while air consumption is measured with air-box method. In catalytic coated engine, piston crown and inner surface of cylinder head are coated with copper by plasma spraying. A bond coating of Ni-Co-Cr alloy is applied (thickness, 100 μ) using a 80 kW METCO plasma spray gun. Over bond coating, copper (89.5%), aluminium (9.5%) and iron (1.0%) are coated (thickness 300 μ). The coating has very high bond strength and does not wear off even after 50 h of operation [13]. CO and UBHC emissions in engine exhaust are measured with Netel Chromatograph analyzer. Nitrogen oxide levels were measured with NOx Analyzer. The catalyst was prepared by using zeolite and lanthanum ion salt. Ion exchange was done by stirring 500 grams of zeolite in a 2N solution of lanthanum (III) salt for 5-6 hours at 70-80^{o}C. [22]. Ion exchanged zeolite was recovered by filtration and activated by calcinations in an oven at 400^{o}C for 3 hours and was furnace cooled to retain mechanical properties. Modified zeolite (Catalyst-A) so obtained was placed in catalytic chamber which had a cylindrical shape with a diameter of 120 mm and length 600 mm. Infusion of urea on lanthanum exchanged zeolite (catalyst-B) was made by gravity feed dosing system.

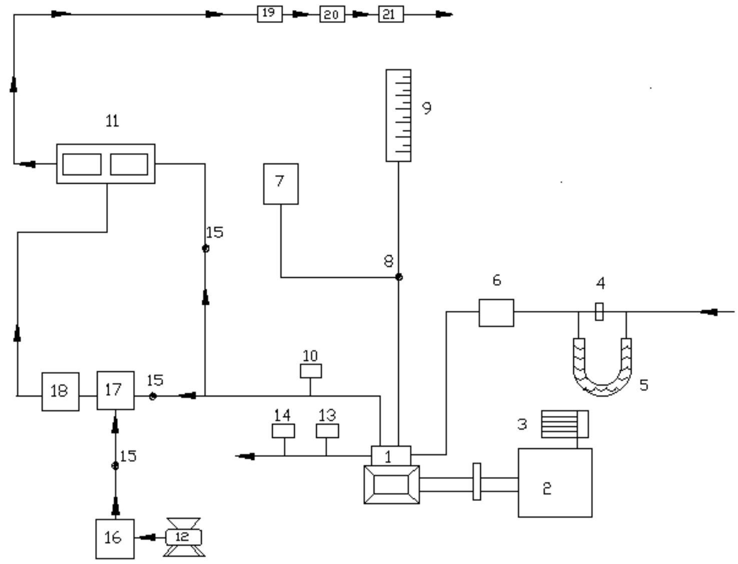

Figure.1. Experimental Set Up

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. NOx Analyzer along with catalytic converter, 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. NOx Analyzer 21. Catalytic converter

A nozzle was used to generate fine spray of urea solution into exhaust gas before it entered into catalytic chamber containing lanthanum exchanged zeolite. NOx emissions were controlled with use of different catalysts in both versions of the engine at peak load operation of the engine.

A catalytic converter[15] (Fig.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 were carried out on CE and CCE with different test fuels [neat gasoline and methanol blended gasoline] 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.

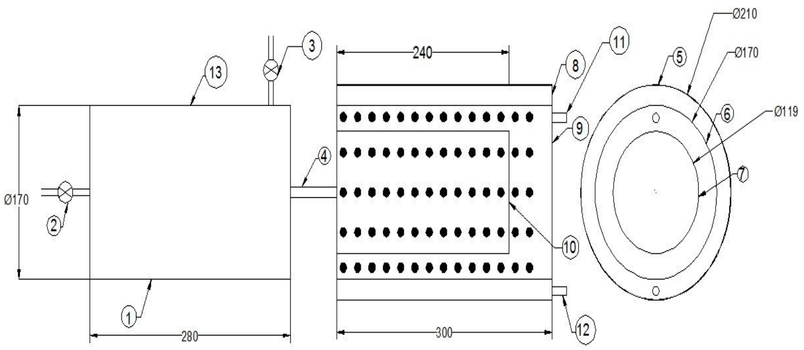

Figure.2. Details of catalytic converter.

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. Intermediate-cylinder, 7. Inner-cylinder, 8.Outer sheet, 9.Intermediate sheet, 10. Inner sheet, 11. Outlet for exhaust gases, 12. Provision to deposit the catalyst, and 13. Insulation.

Fig. 3 shows the variation of CO emissions with BMEP in both versions of the engine with both test fuels. Methanol blended gasoline decreased CO emissions at all loads when compared to pure gasoline operation on CCE and CE, as fuel-cracking reactions are eliminated with methanol. The combustion of alcohol produces more water vapor than free carbon atoms as ethanol has lower C/H ratio of 0.25 against 0.5 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 reduces CO emissions in comparison with CE. Copper or its alloys acts as catalyst in combustion chamber, whereby facilitates effective combustion of fuel leading to formation of CO_2 instead of CO

3.RESULTS AND DISCUSSION

Fig. 4 shows the variation of UBHC emissions with BMEP in both versions of the engine with both test fuels. 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. Catalytic converter decreased 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 CO_2. As compression ratio decreases, pollutants decrease marginally with both versions of the engine, due to increase of EGT with decrease of compression ratio leading to increase of oxidation in exhaust-manifold causing a reduction of pollutants. CCE reduced pollutants when compared to CE at all speeds and compression ratios. Pollutants decreased with increase of speeds with different test fuels in different versions of the engine due to efficient combustion with increase of turbulence with speed.

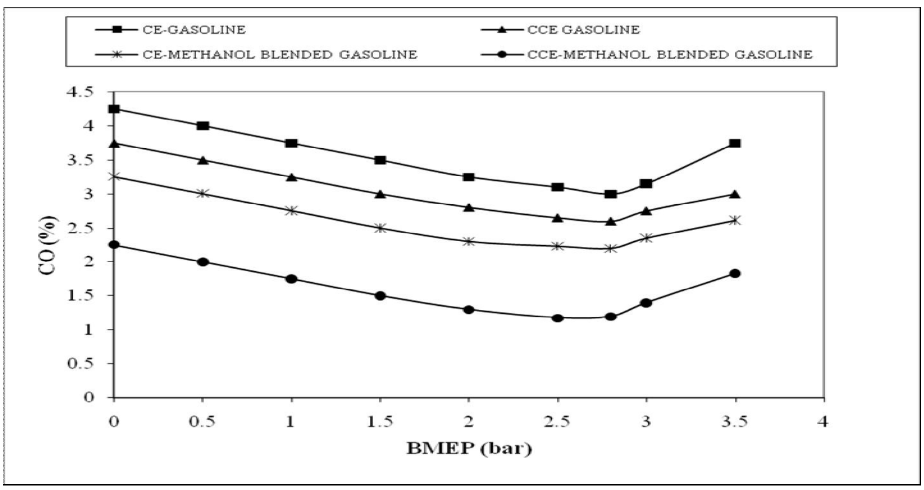

Figure. 3 Variation of carbon monoxide emissoins (CO) with BMEP in CE and CCE with test fuels with a comression ratio of 9:1 and at a speed of 3000 rpm.

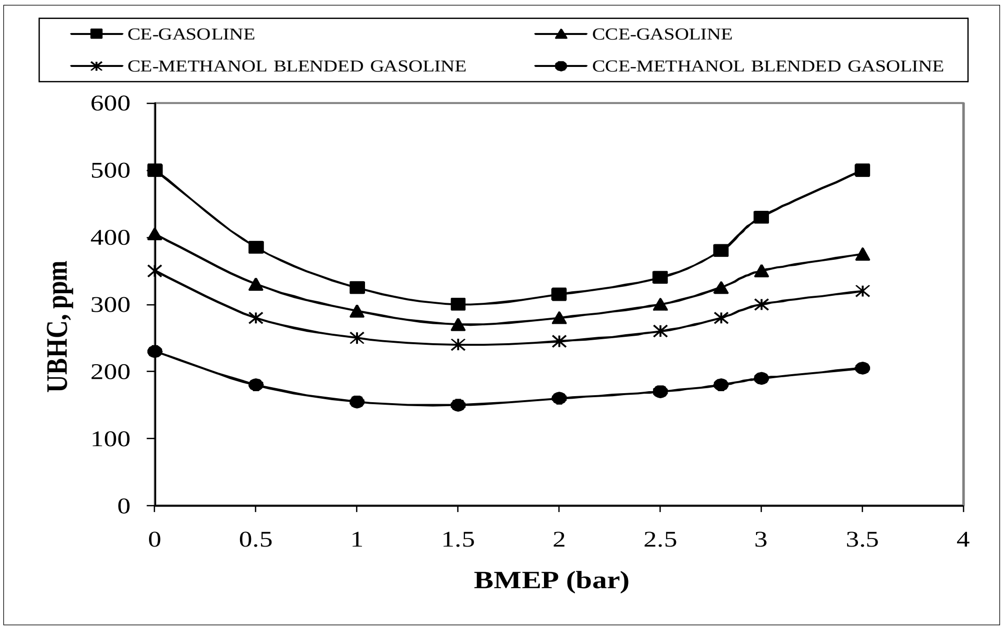

Figure. 4 Variation of un-burnt hydro carbons (UBHC) with BMEP in CE and CCE with test fuels with a comression ratio of 9:1 and at a speed of 3000 rpm.

Table-1 shows the data of CO and UBHC emissions with different test fuels with different configurations of the engine at different operating conditions of the catalytic converter with sponge iron as catalyst.

Void ratio was maintained as 0.6, mass of catalyst was kept as 2kg, air flow rate was kept as 60 l/minute, for achieving maximum reduction efficiency of catalyst [16]. From Table, it can be observed that CO emissions and UBHC 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 and UBHC emissions in both configurations of the engine. Set-C reduced pollution levels effectively with increased oxidation rate of reaction.

Table-1 Data of 'co' emissions (%) and UBHC emissions (ppm) in four-stroke SI engine with different Test fuels

Set	Conventional Engine				Copper coated engine			
	Neat Gasoline		Methanol blended gasoline		Neat Gasoline		Methanol blended gasoline	
	CO	UBHC	CO	UBHC	CO	UBHC	CO	UBHC
Set-A	3.75	500	2.61	320	3.0	375	1.83	205
Set-B	2.25	300	1.52	135	1.8	206	1.07	105
Set-C	1.5	200	0.81	**90**	1.2	**105**	0.58	**65**

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.

Fig.5 presents bar charts showing the variation of NO_x levels with different versions of the engine with test fuels. Methanol blended gasoline reduced NO_x levels effectively in comparison with neat gasoline with both versions of he engine. High latent heat of vaporization of methanol might have reduced combustion temperatures leading to decrease NO_x levels. However, CCE marginally increased NO_x emissions, as combustion chamber was more hot.

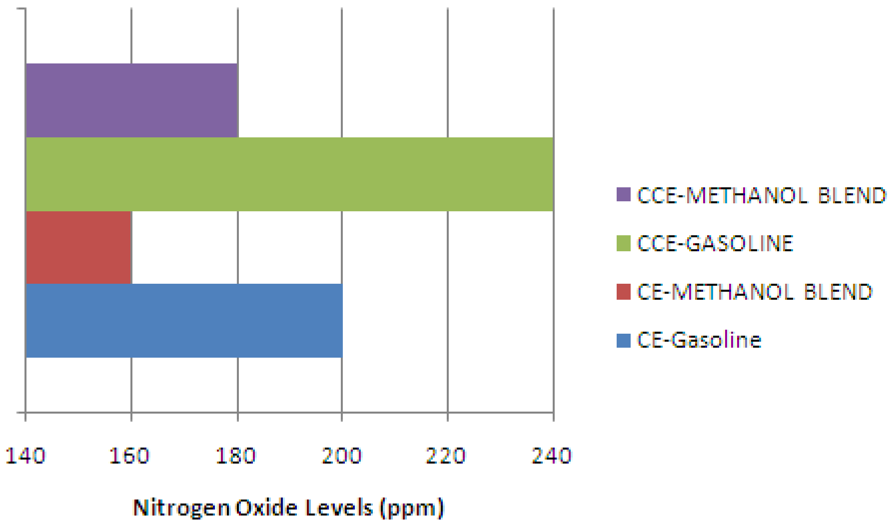

Figure.5. Bar charts showing the variation of nitrogen oxide levels with different versions of the engine with test fuels.

Table.2 presents data of nitrogen oxide levels with different versions of the engine with test fuels with the application of catalyst-A and Catalyst-B. Catalyst-A significantly reduced nitrogen oxide levels in both versions of the engine, with test fuels while catalyst-B further reduced nitrogen oxide levels due to absorption of temperatures by zeolite as zeolite has high surface area.

Table.2 Data of nitrogen oxide levels(ppm)

Set	Conventional Engine		Copper coated engine	
	Neat Gasoline	Methanol blended gasoline	Neat Gasoline	Methanol blended gasoline
Without Catalyst	200	160	240	180
Catalyst-A	160	120	190	140
Catalyst-B	120	90	150	110

4.CONCLUSIONS

On basis of fuel:

CO and UBHC in exhaust decreased by 30% and 36% respectively in CE with methanol blended gasoline when compared to neat gasoline operation. CO and UBHC in exhaust decreased by 39% and 45% respectively in CCE with methanol blended gasoline when compared to neat gasoline operation.

Nitrogen oxide levels in exhaust decreased by 20% in CE, while 25% in CCE with methanol blended gasoline when compared to neat gasoline operation.

On the basis of configuration:

With neat gasoline operation, CCE reduced CO emissions by 20%, UBHC emissions by 25% in comparison with CE . With methanol blended gasoline, CCE reduced CO emissions by 31%, UBHC emissions by 36% in comparison with CE .

With provision of catalyst

CO and UBHC emissions reduced by 40% with Set-B operation, while they decreased by 60% with Set –C operation in comparison with Set-A operation.

NOx emissions reduced by 20% with Catalyst-A, while they decreased by 40% with Catalyst-B operation in comparison with without catalyst.

5.ACKNOWLEDGEMENTS

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