Control of Carbon Monoxide Emissions from Conventional and Copper Coated Two-Stroke SI Engines with Methanol Blended Gasoline with Catalytic Converter Employing Catalysts

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Abstract- Experiments were conducted to evaluate and control the carbon monoxide (CO) 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 carbon monoxide (CO) emissions were determined at different values of void ratio, mass of catalyst, air flow rate and temperature of injected air with Netel Chromatograph CO analyzer. Copper coated combustion chamber with methanol 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 engine, methanol blended gasoline, catalytic converter, catalyst, sponge iron, manganese ore

I. Introduction

Fast depletion of gasoline fuels their ever increasing costs and the increase of pollutants with these fuels forces a search for alternate fuels. Alcohols (methyl alcohol and ethyl alcohol) are the probable alternate fuels, because of their compatibility with petroleum fuels. No major engine design modification is needed, if small quantities of alcohols are blended with gasoline. The change in fuel composition like blending of petrol with methanol is one of the methods adopted to improve the combustion characteristics of the engine. The major predominant emissions from SI engines when run with alcohols are CO emissions. As the exhaust emissions of CO (%) cause harmful health hazards on human beings and on environment, necessarysteps are to be taken in the form of changing the fuel composition or engine design modification or both, to decreasethem. 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. 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. 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.

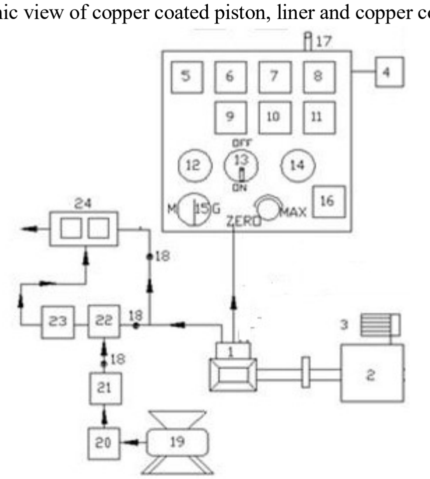
The present paper evaluated the variation of CO emissions of copper coated combustion chamber at different values of void ratio, mass of catalyst, air flow rate and temperature of injected air. Methanol blended gasoline in CCE with sponge iron catalyst found to decrease the % CO emissions over CE with pure gasoline operation.

The rest of the paper is organized as follows. Experimental Programme was explained in section II. Experimental results and discussion are presented in section III. Conclusions are given in section IV.

II. EXPERIMENTAL PROGRAMME

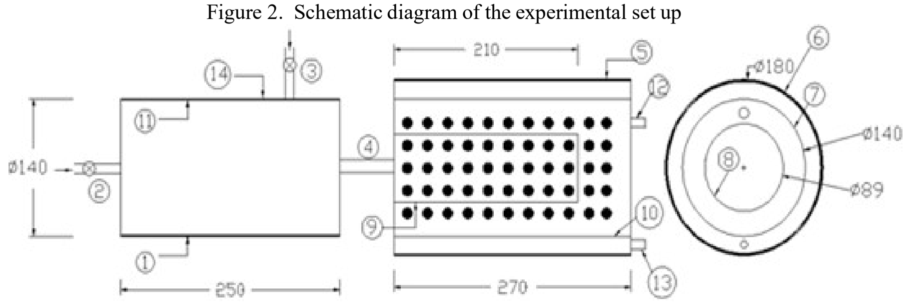
In the catalytically activated engine, by flame spraying technique, a high thermal conductive catalytic material like copper was coated on the cylinder head inside surface and top surface of piston crown. For 100µ thickness, nickel-cobalt-chromium bond coating was sprayed. On this coating, for another 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]. Figure 1 shows the Photographic view of copper coated piston, liner and copper coated cylinder head.

Figure 1 Photographic view of copper coated piston, liner and copper coated cylinder head



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,

Figure 2. Schematic diagram of the experimental set up



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.3. Details of Catalytic converter

Figure 2 shows the experimental set up to determine CO emissions, while Figure 3 shows the details of catalytic converter employed to control CO emissions. The catalytic converter [6] is fitted to exhaust pipe of engine [7]. 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.

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.

III. RESULTS AND DISCUSSION

The variation of CO emissions at the full load operation of the base engine with void ratio under various sets of catalytic converter employing sponge iron (SPI) catalyst was shown in the Figure 4.

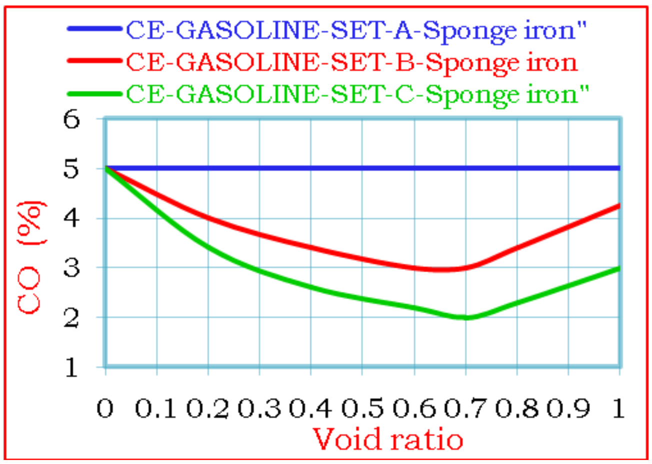


Figure 4 Variation of CO emissions at full load operation of the base engine with void ratio under working sets of catalytic converter with SPI catalyst

From the Figure 4, a decrease in the CO emissions was noticed with an increase in the void ratio under various conditions of operation of a catalytic converter. When the void ratio is increased over and above the value of 0.7 lesser decrease in CO emissions was observed. This was because of increased back pressure on the engine and reduced surface to volume ratio.

The variation of CO emissions at the full load operation of the base engine with void ratio under various working sets of catalytic converter using manganese ore (Mn ore) catalyst was shown in the Figure 5.

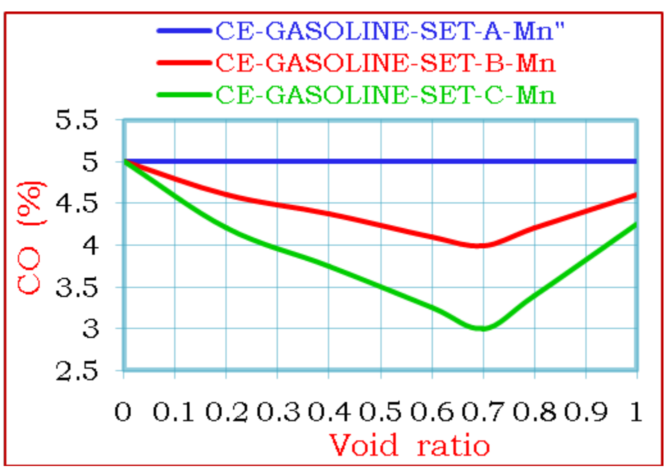


Figure 5 Variation of CO emissions at full load operation of the base engine with void ratio under working sets

of catalytic converter with Mn ore catalyst

It was evident from the Figure 5 that, when the void ratio touches a value of 0.7 maximum reductions in CO emissions was observed with Mn ore catalyst. But this decrease in CO emissions was less in comparison with SPI catalyst.

Figure 6 shows the variation of CO emissions at the full load operation of the catalytic coated engine running with the base fuel with void ratio under working conditions of catalytic converter using SPI catalyst.

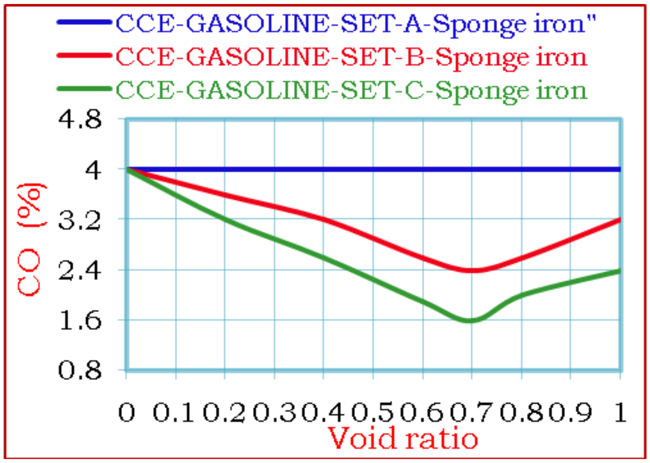


Figure 6 Variation of CO emissions at full load operation of CCE using base fuel with void ratio under various working sets of catalytic converter with SPI catalyst

The variation of CO emissions at the full load operation of the catalytic coated engine running with the base fuel with void ratio under working conditions of catalytic converter using Mn ore catalyst was shown in the Figure7.

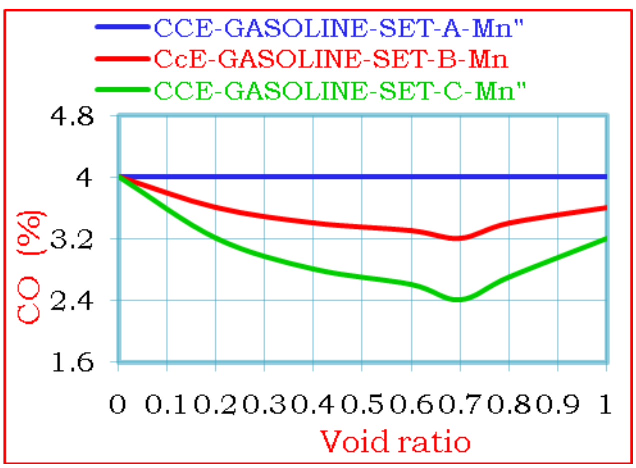


Figure 7 Variation of CO emissions at full load operation of CCE using base fuel with void ratio under working sets of catalytic converter with Mn ore catalyst

The curves of the Figure 6 and Figure 7 exhibited same trends as in the Figure 4. The ideal void ratio was 0.7 under various versions of the engine among the catalysts employed in the catalytic converter.

The variation of CO emissions at the full load operation of the base engine with the mass of SPI catalyst under various sets of catalytic converter was shown in the Figure 8. The curves of Figure 8 shows that, as the mass of SPI catalyst increased the CO emissions were decreased. At a 2 kg mass of SPI catalyst, minimum CO emissions were observed. However, with the mass of SPI catalyst exceeding 2 kg, CO emissions were not reduced further because of completion of oxidation at 2 kg which is the ideal mass. Figure 9 shows the variation of CO emissions at the full load operation of the base engine with the mass of Mn ore catalyst under various sets of catalytic converter. The curves in the Figure 9 exhibit a decrease in the CO emissions with an increase in the mass of Mn ore catalyst. At 2.5 kg of Mn ore minimum CO emissions were observed. The mass of Mn ore catalyst used in excess of 2.5 kg will not result any further reduction in the CO emissions. This was due to high density of Mn ore in comparison with SPI catalyst.

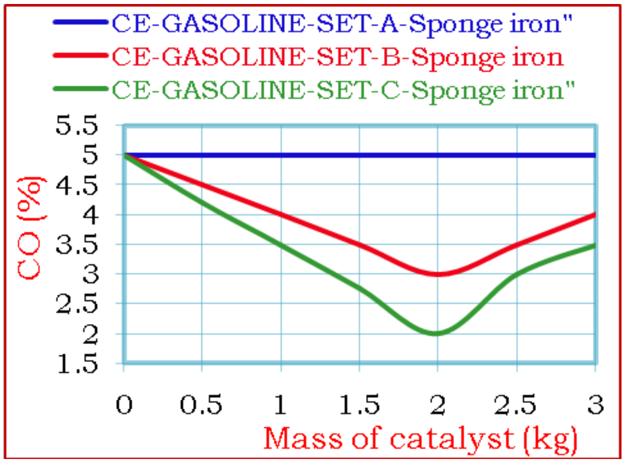


Figure 8 Variation of CO emissions at full load operation of the base engine with the mass of SPI catalyst under various working sets of catalytic converter

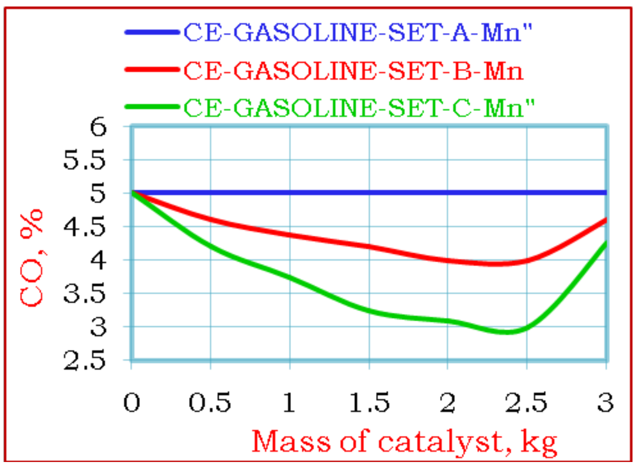


Figure 9 Variation of CO emissions at full load operation of the base engine with the mass of Mn ore catalyst under various working sets of catalytic converter

The variation of CO emissions at the full load operation of the catalytic coated engine running on the base fuel with the mass of SPI catalyst under various sets of catalytic converter was shown in the Figure 10 which shows similar trends as Figure 9.

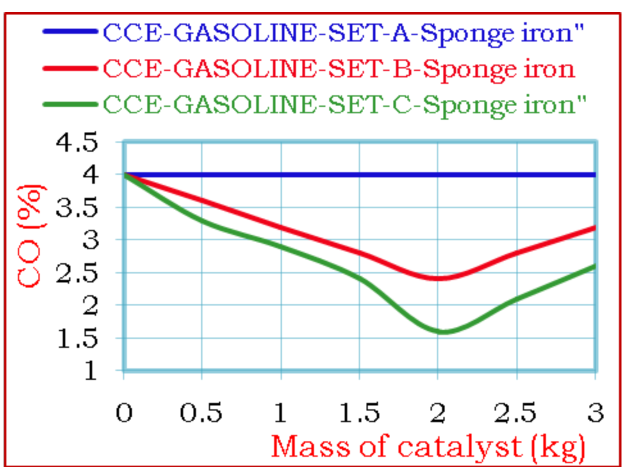


Figure 10 Variation of CO emissions at full load operation of CCE using base fuel with the mass of SPI catalyst working under various sets of catalytic converter

The variation of CO emissions at the full load operation of the catalytic coated engine running on the base fuel with the mass of Mn ore catalyst under various sets of catalytic converter was shown in the Figure 11.

Similar observations were noticed with catalytically activated engine to those of base engine with various catalysts. Therefore the behavior of Figure-6.19 was the same as that of Figure-6.17.

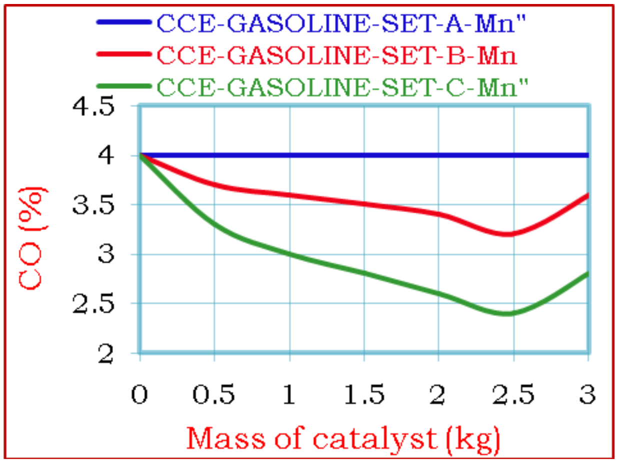


Figure 11 Variation of CO emissions at full load operation of CCE using base fuel with the mass of Mn ore working under various sets of catalytic converter

The variation of CO emissions at full load operation of the base engine and catalytic coated engine using experimental fuels and SPI catalyst at ideal void ratio (0.7), with air flow rate was shown in Figure 12. In order to reduce the pollutants more effectively there was provision for air injection in to the catalytic converter.

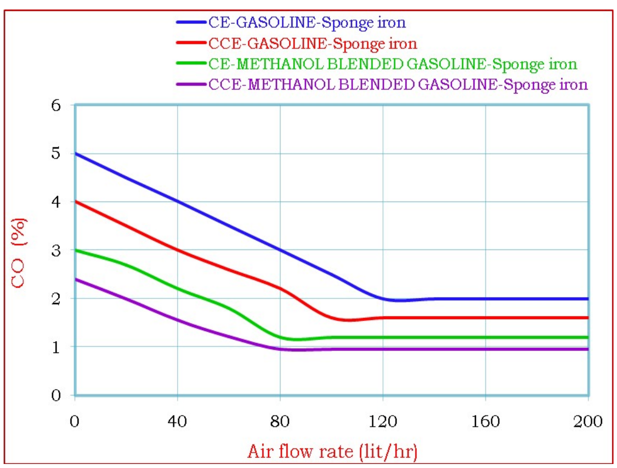


Figure 12 Variation of CO emissions with air flow rate in the catalytic converter using test fuels and SPI catalyst for the base engine and catalytic coated engine

From the curves of Figure 12, it was evident that percentage of CO emissions was minimum when 120 lit/hr (or, 2 lit/min) and 100 lit/hr of air respectively was injected in to the base engine and catalytic coated engine when operating with base fuel while, minimum CO emissions was observed when 80 lit/hr of air each was injected in to both the engines when run with methyl alcohol blend. This quantity of air flow rate to the catalytic converter was maintained throughout the experimentation. As low residence time was associated with excessive rate of airflow and insufficient oxidation reaction to change CO to CO_2 was the result of lower rate of airflow, methyl alcohol blend in CCE that requires lower rate of airflow in comparison with the base engine, results lower CO emissions. The % increase in overall efficiency of the system was 60% for CE and 68% for CCE with the provision of air injection in to the catalytic converter.

Figure 13 presents the variation of CO emissions at full load operation of the base engine and catalytic coated engine using test fuels and Mn ore catalyst at ideal void ratio (0.7), with air flow rate.

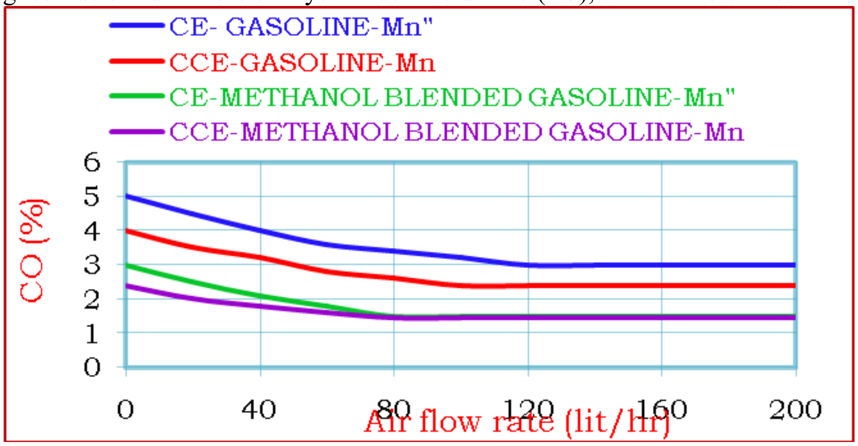


Figure 13 Variation of CO emissions with air flow rate in the catalytic converter using test fuels and Mn ore catalyst for base engine and catalytic coated engine

Figure 14 shows the variation of CO emissions at full load operation of the base engine and catalytic coated engine using experimental fuels and SPI catalyst at the ideal void ratio (0.7), with the temperature of injected air (^{0}C) at an air flow rate of 120 lit/hr.

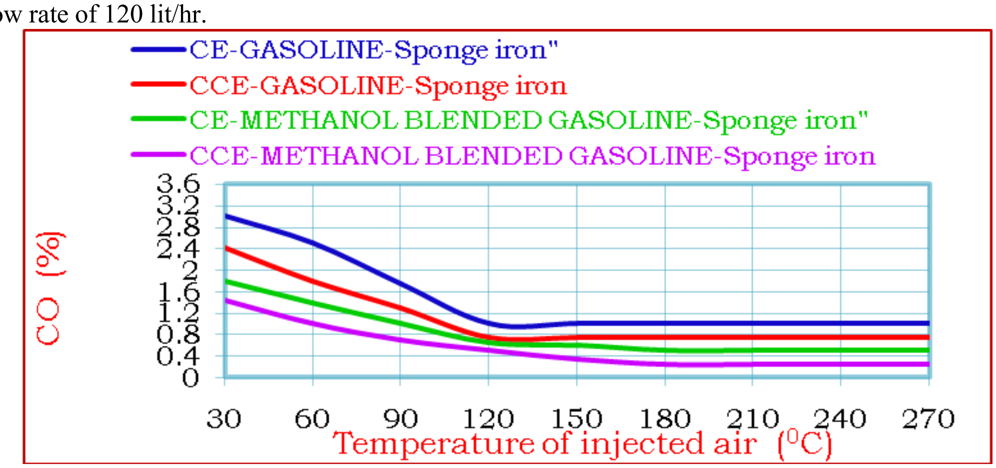


Figure 14 Variation of CO emissions with the temperature of air injected in to the catalytic converter for the base engine and CCE using test fuels and SPI catalyst

It was noticed from the Figure 14 that, rise of temperature of injected air resulted in the reduction of CO emissions in both engine versions using experimental fuels. When the base fuel was used in the base engine and catalytic coated engine, at a temperature of 120^{0}C, minimum CO emissions were observed while, with methyl alcohol blend minimum CO emissions were recorded at a temperature of 180^{0}C.

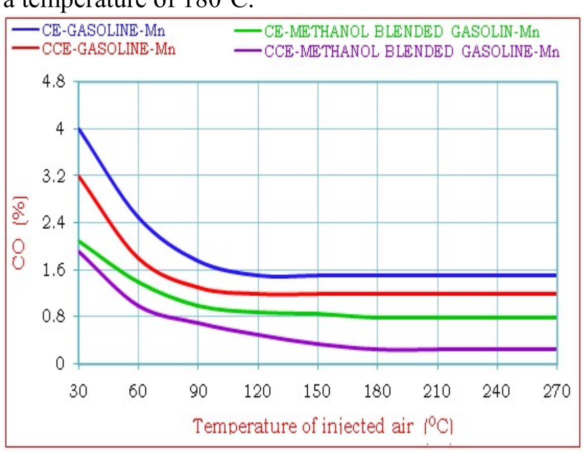


Figure 15 Variation of CO emissions with the temperature of air injected in to the catalytic converter for the base engine and CCE using test fuels and Mn ore catalyst

Figure 15 shows the variation of CO emissions at full load operation of base engine and catalytic coated engine using both fuels and Mn ore catalyst at the ideal void ratio (0.7), with the temperature of injected air (^{0}C) at an air flow rate of 120 lit/hr. The trends of the curves in the Figure 15 are similar to those of Figure 14. Lesser decrease in CO emissions was observed with Mn ore catalyst in comparison with SPI catalyst. 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^{0}C 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.

IV.CONCLUSIONS

1. With base fuel in the base engine and catalytically activated engine, the CO emissions were lower at a void ratio of 0.7.
2. With experimental fuels in the both configurations of the engine, lower CO emissions were observed with 2 kg mass of catalyst.
3. Lower CO emissions were noticed with base fuel operation when the air flow rate was 120 lit/hr for the base engine and 100 lit/hr for the catalytic coated engine, while it was 80 lit/hr for both configurations of the engine with methyl alcohol blend.
4. With base fuel operation in both configurations of the engine, CO emissions were lower when air was injected in to the catalytic converter at a temperature of 120^{0}C while, it was 180^{0}C with methyl alcohol blend.
5. Catalytic coated engine with methyl alcohol blend and sponge iron catalyst decreased the CO emissions by 71% and 67% without air injection, while the emissions were decreased by 81% with air injection in comparison with the base engine.
6. With methyl alcohol blend and manganese ore catalyst, catalytic coated engine decreased the CO emissions by 62% without air injection, while they were decreased by 72% with air injection, in comparison with the base engine operation.
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.

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