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# Studies on exhaust emissions from copper coated, four stroke spark ignition engine with catalytic converter with methanol blended gasoline

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**Abstract:-** The major exhaust emissions from spark ignition engine operating with gasoline fuel are carbon monoxide (CO) and unburnt hydrocarbons (UBHC), which are hazardous to human beings and environment. However, if the engine is operated with methanol blended gasoline, aldehydes are also to be taken into consideration. Experiments were carried out on a Copper coated spark ignition engine operated with methanol blended gasoline (20% v/v), fitted with a catalytic converter containing Sponge Iron as catalyst. The influence of engine parameters such as speed, compression ratio and configuration of the combustion chamber with and without catalytic converter on the exhaust emissions is studied. Comparative studies were made with a conventional engine using pure gasoline as fuel. The speed of engine has marginal effect, while compression ratio has strong influence on reduction of pollutants. Air injection into the catalytic converter has further reduced the pollutants considerably.

**Keywords:-** Spark ignition engine, Exhaust emissions, Copper coating, Catalytic converter, Air injection and Methanol blended gasoline.

## I. INTRODUCTION

This paper is divided into 1) Introduction, 2) Materials and methods, 3) Results and discussions, 4) conclusions, 5) acknowledgements, 6) abbreviations and 7) references.

This section contains information about formation of emissions from SI engine, their effect on human health and environment, modification of engine to improve the performance and reduce the emissions.

CO forms during combustion process. In fuel rich mixtures, there is insufficient Oxygen to burn the complete Carbon in the fuel. In fuel lean mixtures, non-homogenous mixture in the combustion chamber may result in rich pockets resulting in CO formation. Partial oxidation of hydrocarbons in exhaust stream is another source for CO [3]. Carbon monoxide is a colourless, tasteless, odourless and non-irritating gas. When inhaled, it enters the blood stream through lungs and forms a tight complex with Haemoglobin, called Carboxyhemoglobin (COHb). COHb decreases the Oxygen carrying capacity of the blood, resulting in tissue Hypoxia. CO poisoning causes headache, dizziness, nausea, vomiting, disorientation and visual disturbance. Skeletal muscle necrosis, renal failure, pancreatitis and hepatocellular injury can also occur as a result of CO poisoning [13].

Engine exhaust contains various hydrocarbons such as, Paraffins, Olefins, Acetylene and Aromatic compounds. Four possible mechanisms contribute to the formation of UBHC. (1) Flame Quenching due to parts in combustion chamber [1], (2) Seepage of unburned gases into crevices and small openings in the combustion chamber [9], (3) Absorption and desorption of fuel vapour into the oil present in the cylinder [5] and (4) Incomplete combustion of fuel in a fraction of engine's fuel cycles [3]. UBHC are carcinogenic in nature. Hydrocarbons react in presence of Nitrogen Oxides and Sunlight to form ground level Ozone, resulting in Photochemical Smog [15].

In light of depleting fossil fuels, it has become imperative to search for alternative fuels [6]. The properties of methanol are close to that of gasoline. Methanol has high Octane quality. It rates 106-115 Octane numbers by research method and 88-92 octane numbers by motor octane number [16, 17]. Advantages of methanol over gasoline are: lower production cost, lower flammability thereby reduced risk and lower carbon footprint. In this study, methanol (20% V/V) blended gasoline is used [12]. It requires no major modification in the spark ignition engine. Aldehydes are significant emissions when using Methanol as fuel. Incomplete combustion due to partial oxidation of the un-burnt hydrocarbon fuels results in aldehyde emission. Aldehydes are Carcinogenic and their vapours have detrimental effects on human health including irritation of the eye, throat, nose, asthma and pulmonary function [11, 14].

Copper coating over piston crown and cylinder walls has been reported to increase the fuel economy and combustion stabilization [2, 10]. In addition, instead of using Platinum group metals, which is quite expensive as catalyst, sponge iron is used in the catalytic converter [7, 8]. In this study, emissions are recorded under different versions of combustion chamber, compression ratios and various configurations of catalytic converter.

## II. MATERIALS AND METHODS

This section contains fabrication of copper coated combustion chamber, description of experimental setup, operating conditions of catalytic converter, measurement of CO, UBHC emissions and measurement of aldehydes by wet chemical method.

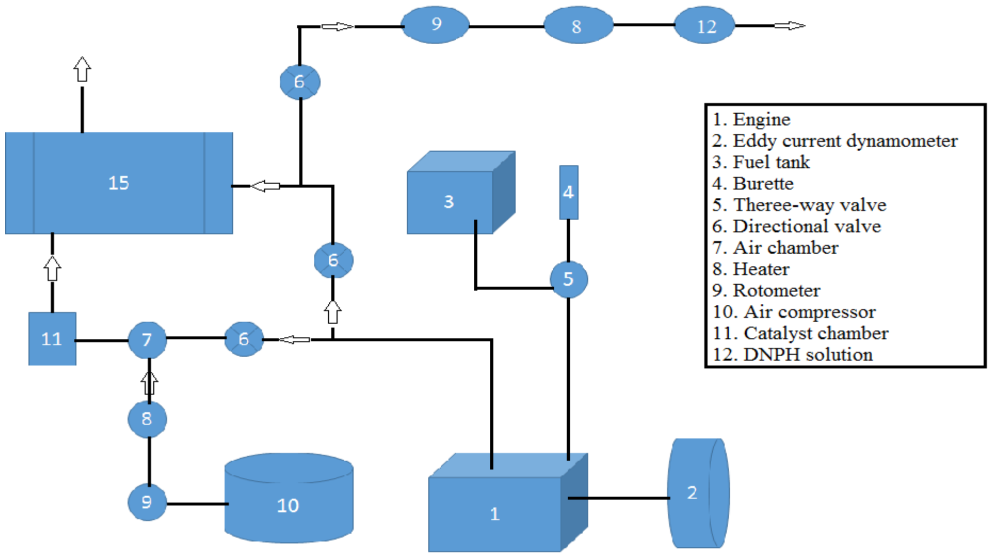
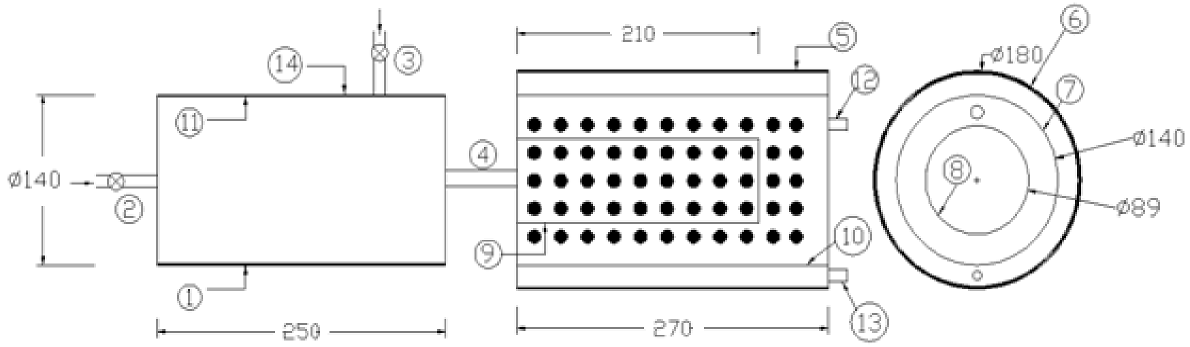



**Fig 1: Experimental setup.**




**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. 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.**

The experimental setup employed in the present study is shown in Fig.1. A four stroke, single-cylinder, water-cooled, spark ignition engine of brake power 2.2KW at rated speed of 3000rpm is used. The engine is coupled to an Eddy current dynamometer for measuring its brake power. The compression ratio of the engine is varied from 8:1 to 9:1 by varying the clearance volume by adjusting the cylinder head threaded to the cylinder. The engine speed can be varied between 2200 to 3000rpm.

The Piston crown and inside surface of the cylinder is coated with copper by Plasma spraying. A bond coating of NiCoCr alloy is applied for thickness of about 100 microns using an 80KW METCO plasma spraying gun. Over the bond coating, copper (89.5%), Aluminium (9.5%) and Iron (1.0%) are coated for 300 microns thickness. The coating has very high bond strength and does not wear off even after 50 hours of operation. A catalytic converter (Fig 2) is fitted to the exhaust pipe of the engine. Provision is made to inject a definite quantity of air into the catalytic converter. The converter is filled with sponge iron catalyst with void ratio (Volume occupied by catalyst to volume of catalytic chamber) of 0.7:1, where the pollutant are found to be minimum [8].

The CO and UBHC emissions in the exhaust of the Engine are measured with Netel Chromatograph analyser. For measuring aldehydes from the exhaust of the engine, DNPH method is employed [4]. The exhaust is bubbled through 2, 4-dinitrophenyl hydrazine (2, 4 DNPH) solution. The hydrazones formed are extracted into chloroform and are analysed by employing high performance liquid Chromatography (HPLC) to find the percentage concentration of Formaldehyde and acetaldehyde in the exhaust of the engine. Exhaust gases are drawn at 3 different locations, (1) immediately after the exhaust valve of the engine, (2) after the catalytic converter, and (3) at the outlet after air injecting into the catalytic converter. The quantity of air drawn from the compressor and injected into the converter is kept constant so that back pressure does not increase and reverse flow is not created in the converter. Experiments are carried out on various configurations of the engine i.e., conventional engine and copper coated engine with different test fuels like pure gasoline and methanol blended gasoline under different operating conditions of the catalytic converter like: 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.

## III. RESULTS AND DISCUSSIONS

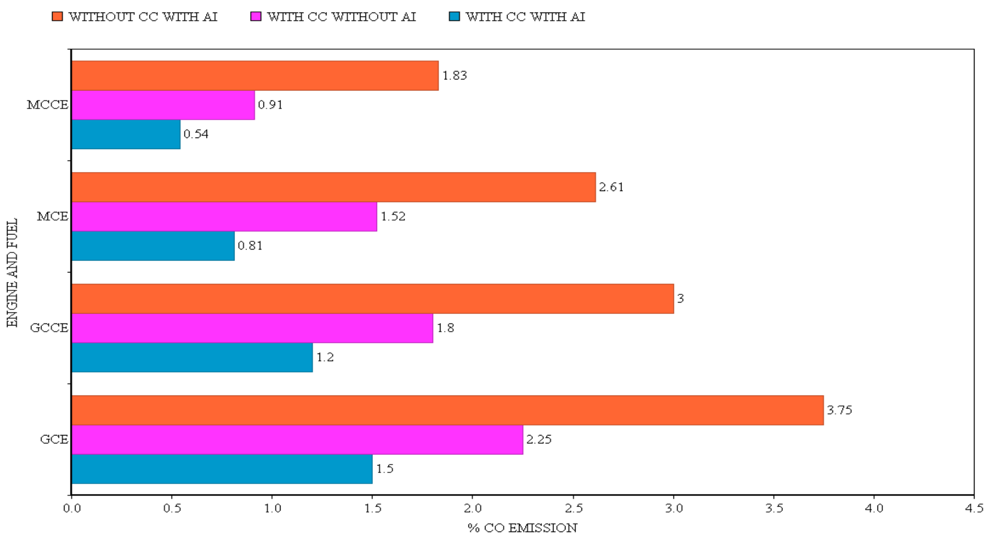



**Fig 3: CO emissions at peak load for different test fuels at CR=9:1 and speed= 3000rpm.**

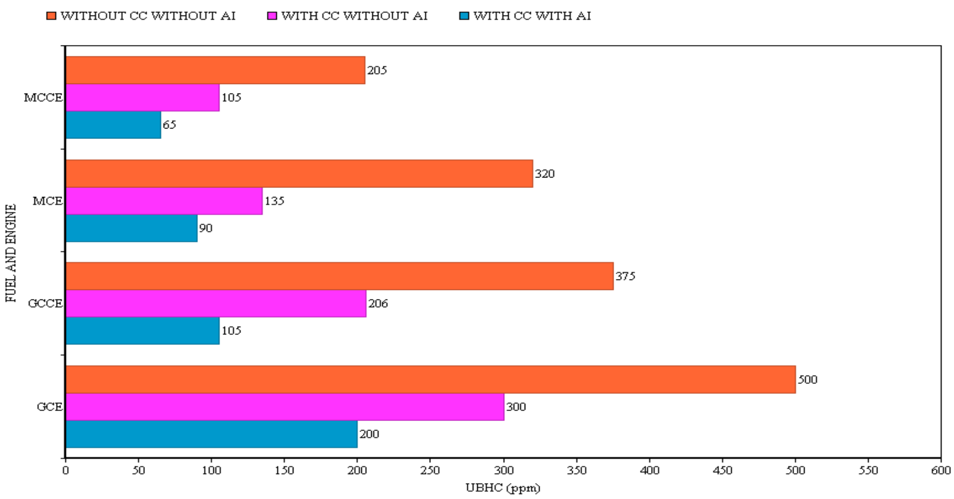



**Fig 4: UBHC emissions at peak load for different test fuels at CR=9:1 and speed= 3000rpm.**

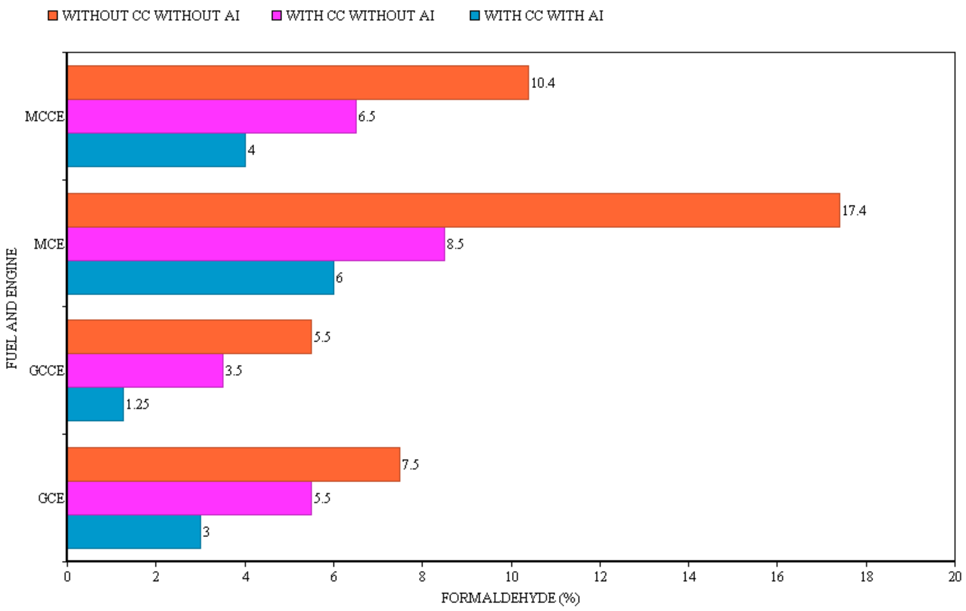



**Fig 5: Formaldehyde emissions at peak load for different test fuels at CR=9:1 and speed= 3000rpm.**

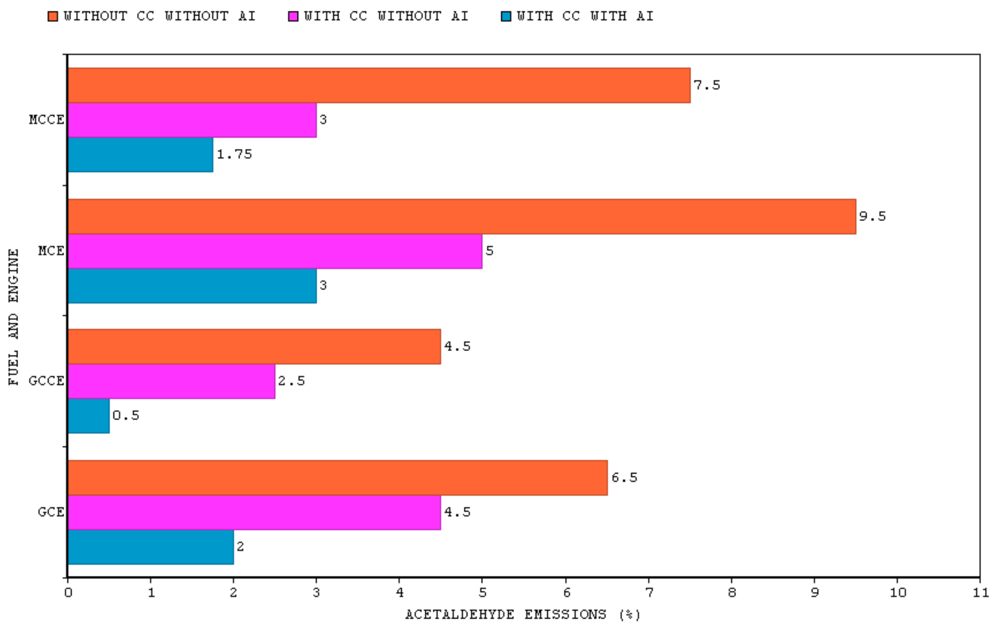



**Fig 6: Acetaldehyde emissions at peak load for different test fuels at CR=9:1 and speed= 3000rpm.**

It could be inferred from Fig 3 that methanol blended gasoline has lower emissions of CO than pure gasoline. Owing to lower C/H ratio of methanol (0.25) against gasoline (0.44), the combustion of methanol based gasoline produces more Water Vapour than free Carbon atoms, which leads to lower CO emissions. Also, the Oxygen present in the structure of Methanol is available for Combustion with MBG and leads to lower CO emissions. Hydrogen is formed when Methanol is dissociated in the Combustion Chamber and it helps the Fuel Air mixture to burn quickly thereby bringing about the complete combustion of carbon present in the fuel to carbon dioxide and carbon monoxide to carbon dioxide. This reduces the CO emissions by increasing the combustibility.

Similarly, from Fig 4, it can be observed that the emission of UBHC reduced by 36% in conventional engine and 45% in copper coated engine by using MBF. This can be attributed to increase in the amount of available oxygen for combustion in methanol blended fuel and reduction of fuel seepage into crevices due to efficient combustion of MBG.

But, as shown in Fig 5, 6 aldehyde emissions increased in Methanol Blended gasoline due to partial oxidation of alcohol to produce formaldehyde and acetaldehyde. But it can be seen from the Fig 5 and 6 that formaldehyde and acetaldehyde emissions reduced by 47% and 61% respectively by employing catalytic converter and copper coated engine in comparison with conventional engine.

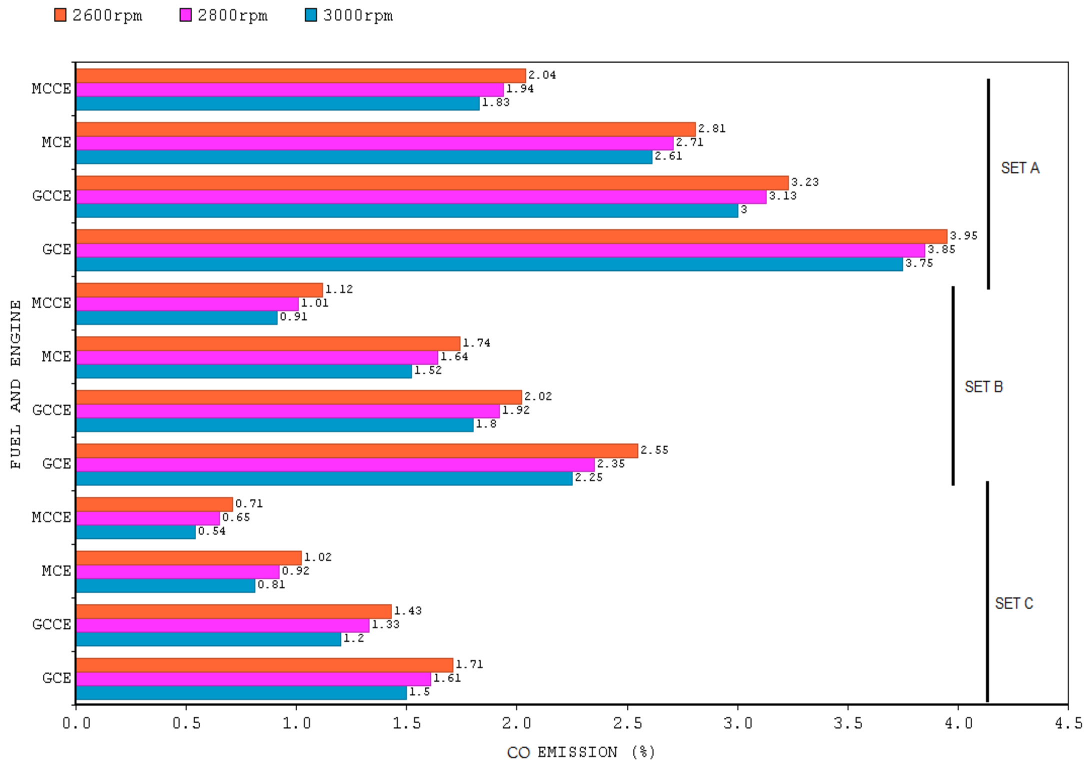



**Fig 7: CO emissions at CR= 9:1 and different speeds.**

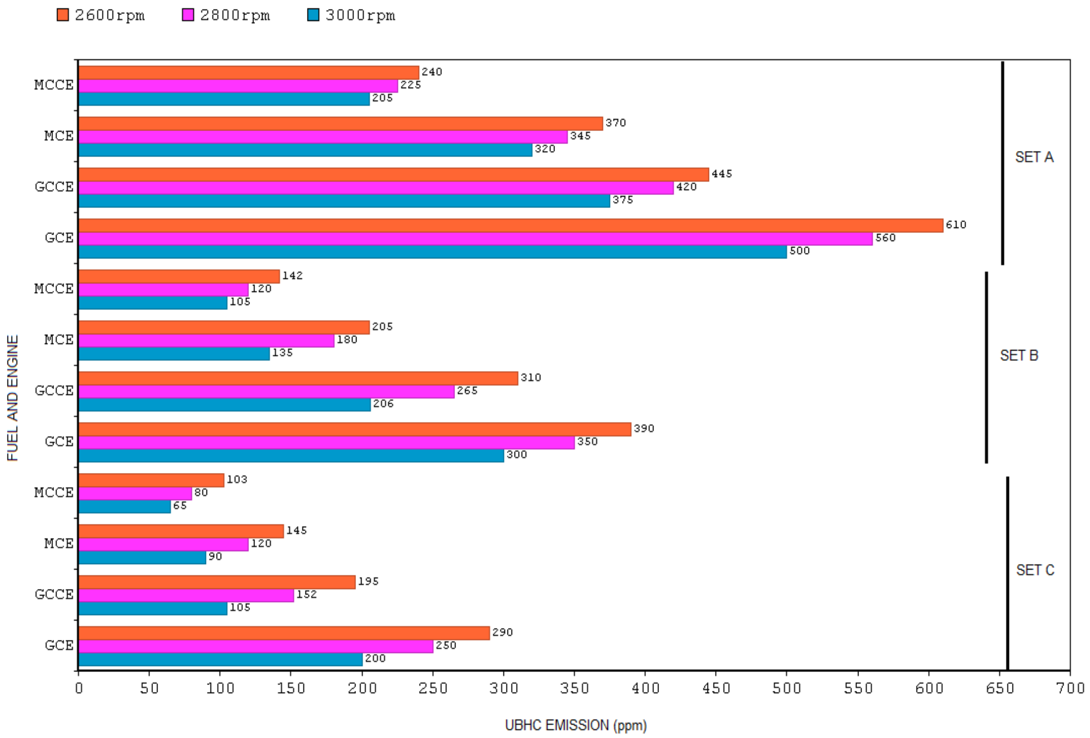



**Fig 8: UBHC emissions at CR= 9:1 and different speeds.**

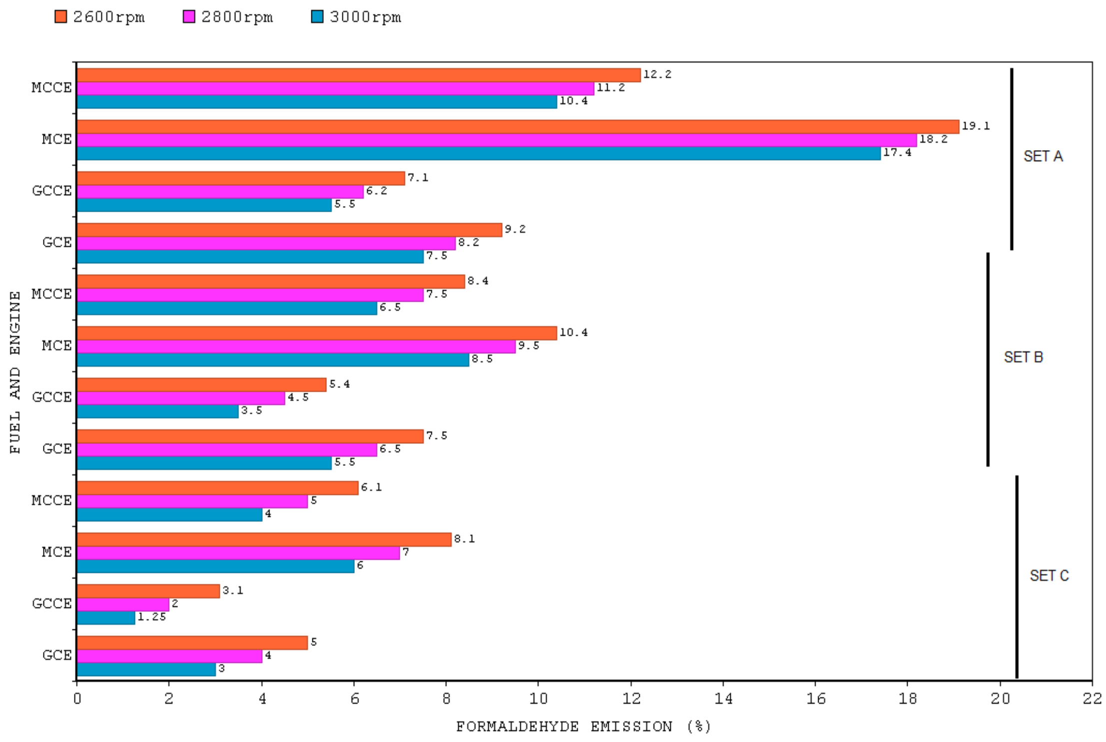



**Fig 9: Formaldehyde emissions at CR= 9:1 and different speeds.**

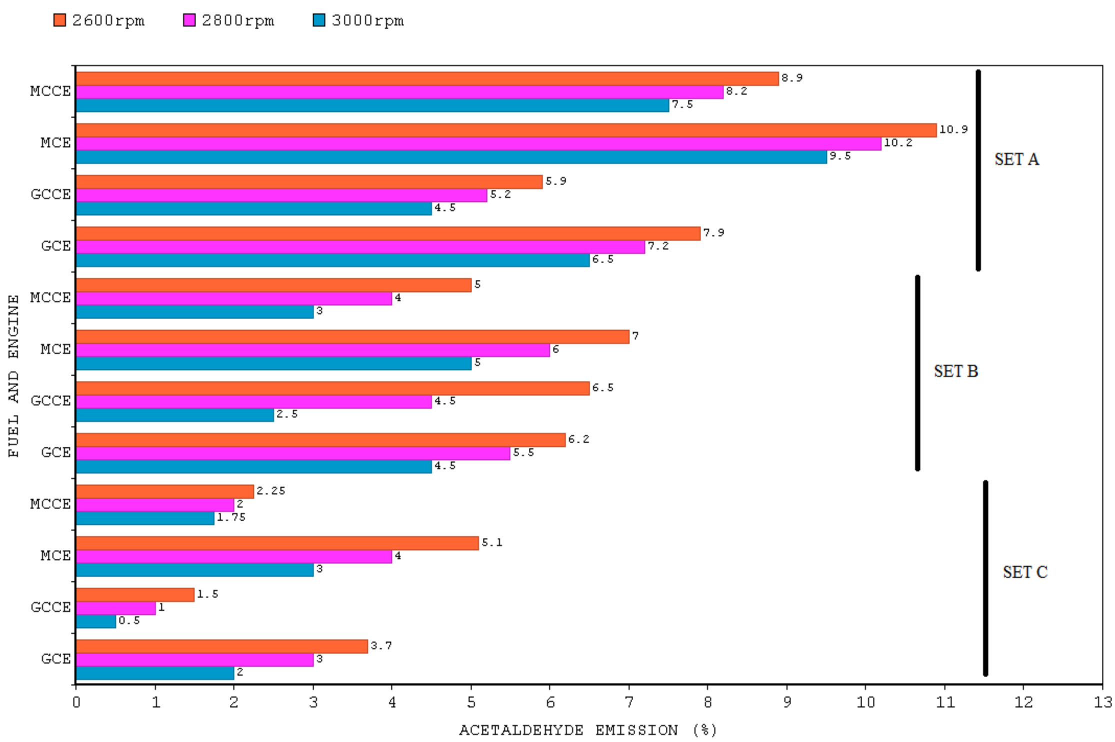



**Fig 10: Acetaldehyde emissions at CR= 9:1 and different speeds.**

It could be seen from Fig 7 that CO emissions decreased with higher speeds of the engine. As speed is increased from 2600rpm to 3000rpm, the turbulence of combustion and hence the speed of the flame increases. Also, increase in exhaust gas temperatures at higher speeds enhances post flame oxidation of UBHC. It could be seen from Fig 8 that increase in speed of engine from 2600rpm to 3000rpm reduced the UBHC emissions from 14 to 37 percent in different configurations of combustion chamber and catalytic converter. Furthermore, in copper coated engines, the catalytic activity increases with temperature. Therefore the emissions are reduced in comparison with conventional Engine.

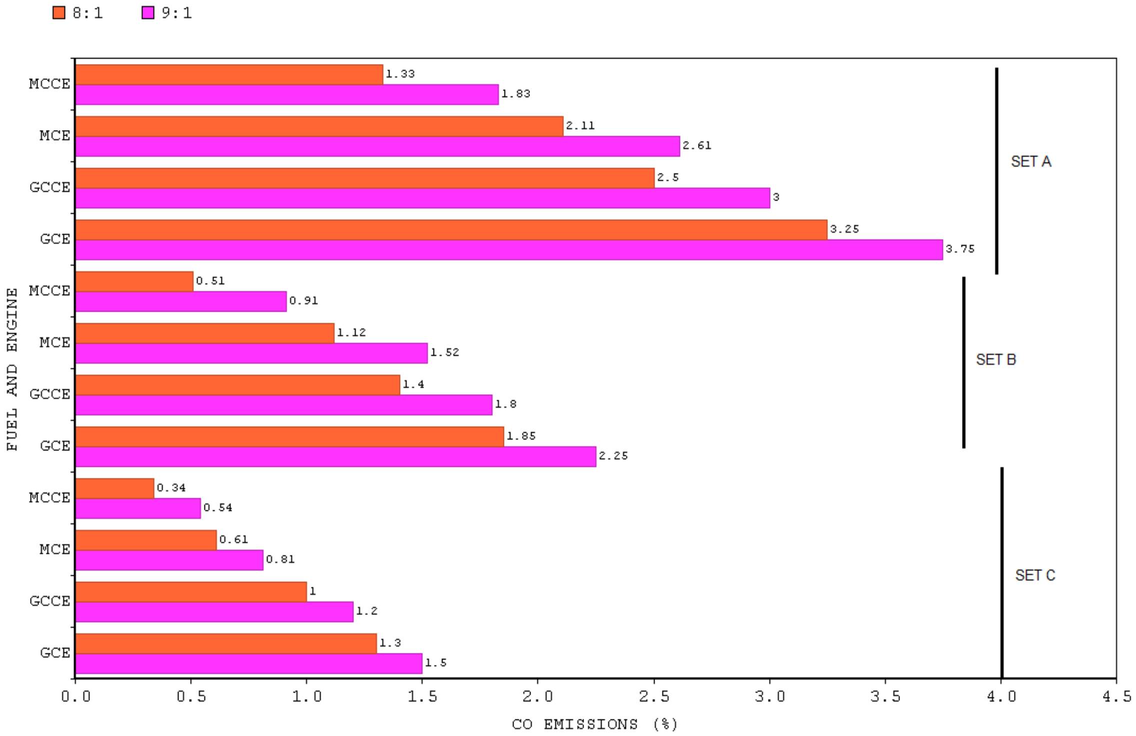



**Fig 11: CO emissions at speed= 3000rpm and different CR.**

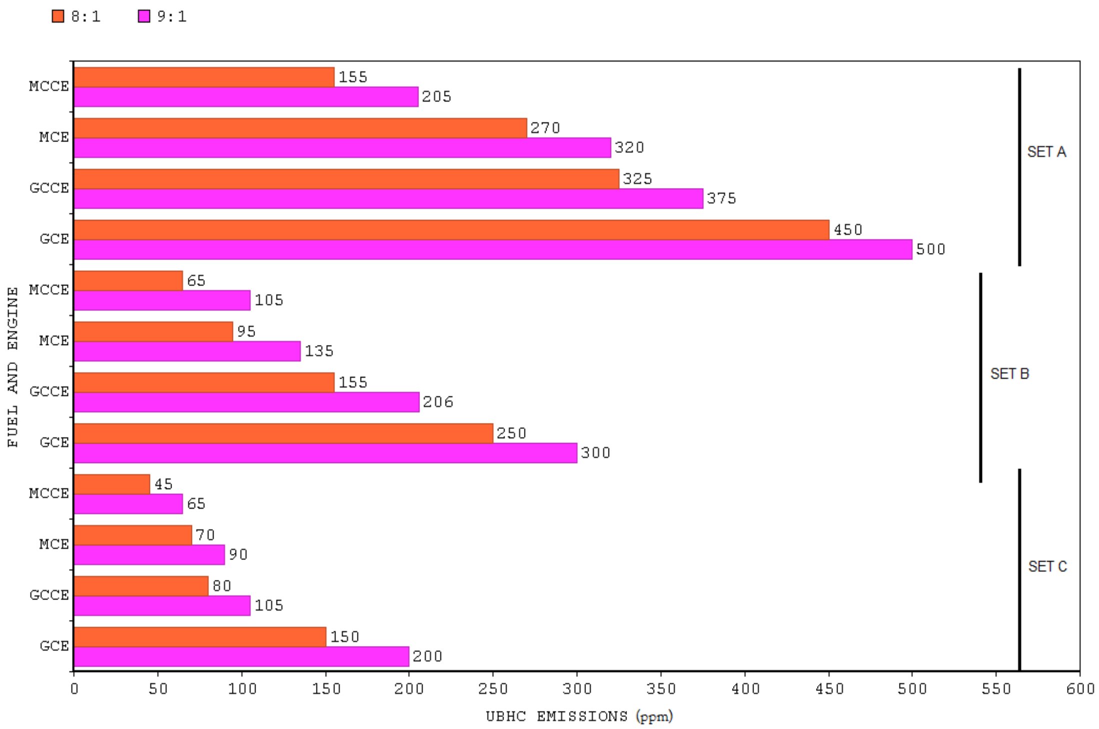



**Fig 12: UBHC emissions at speed= 3000rpm and different CR.**

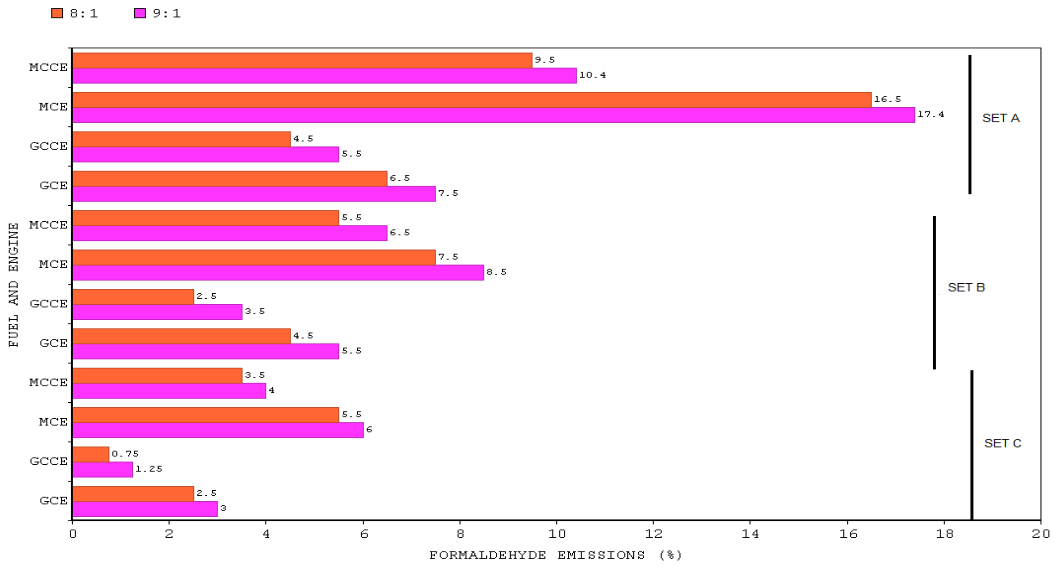



**Fig 13: Formaldehyde emissions at speed= 3000rpm and different CR.**

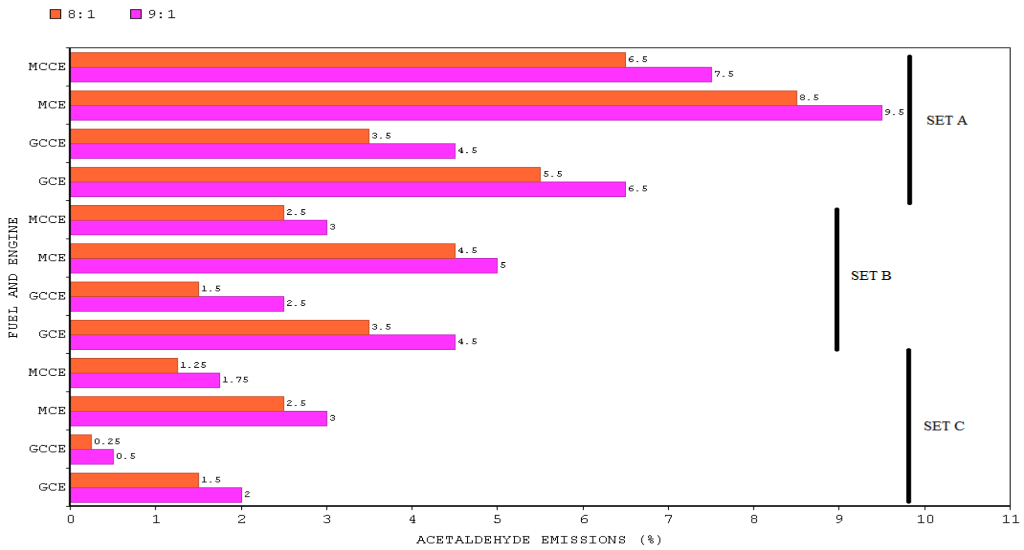



**Fig 14: Acetaldehyde emissions at speed= 3000rpm and different CR.**

It could be seen from the Fig 11, 12, 13 and 14 that the emissions of CO, UBHC and aldehydes decreased with the decrease in CR. This is due to increase in exhaust gas temperature with decrease in compression ratio, leading to oxidation of emissions in the exhaust manifold.

## IV. CONCLUSIONS

The emissions of CO, UBHC and aldehyde at peak load are mitigated by 35-41 % by using Copper coated engine. The pollutants decreased by 11-14% by reducing the compression ratio from 9:1 to 8:1. Also operation of the engine on MBG instead of gasoline decreased the emissions of CO and UBHC by 30- 46%. With methanol blended gasoline, the Formaldehyde emissions are greater than that of acetaldehyde. But the use of catalytic converter reduces the aldehyde emissions drastically.

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## ABBREVIATIONS

1. Set A- Without catalytic converter and without air injection
2. Set B- With catalytic converter and without air injection
3. Set C- With catalytic converter and with air injection
4. CC- Catalytic Converter
5. AI- Air Injection
6. CR- Compression Ratio
7. MBG- Methanol Blended Gasoline
8. UBHC- Unburnt Hydrocarbons
9. GCE- Conventional engine operated with pure gasoline
10. GCCE- Copper coated engine operated with pure gasoline
11. MCE- Conventional engine operated with methanol blended gasoline
12. MCCE- Copper coated engine operated with methanol blended gasoline

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