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Investigations on reduction of pollutants in spark ignition engine

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ABSTRACTS

With a great vulnerability to oil embargoes and shortage of fossil fuels, attention is focussed on development of alternative fuel sources. Therefore alternative fuels like alcohol are preferred due to their comparable properties with gasoline. Reduction of exhaust emissions from engines has been focused and given importance in the development of new engines. The aim of the investigations is to determine and control of pollutants of the variable speed engine with piston surface, coated with copper and also inner side of the cylinder head as well as liner fuelled with gasohol [80% of gasoline blended with 20% of ethanol] by varying timing of spark ignition coupled with catalytic converter using catalyst of sponge iron incorporating air injection in catalytic chamber.The operating conditions of the investigations were configuration of the engine and ignition timing, with and without the provision of catalytic chamber. The exhaust emissions of carbon mono oxide (CO), un-burnt hydro carbons (UBHC) and nitrogen oxide (NO_x) levels were determined at various values of brake mean effective pressure (BMEP) of the engine. CO emissions, UBHC emissions and NO_x levels were evaluated with sophisticated analyzer at various values of BMEP of the engine. Copper coated engine with gasohol at its optimum ignition timing reduced pollution levels. Catalytic converter reduced pollution levels by 40% and further reduction of emissions were pronounced with the injection of air. The ignition timing which was found to be optimum with CE was 28^0bTDC (before top dead centre), while it was 27^0b TDC with copper coated engine (CCE).

Key words : *Ignition engine, Pollutants*

Introduction

The invention of non-fossil fuels started with exhausting fuels in fossil nature, causing an increase of products of combustion. An engine designer's prime objective is to bring maximum thermal efficiency with least pollution levels. To attain it, many researchers applied different alternate and renewable fuels in S.I engines. They found that alcohols are the best alternative fuels for S.I engines, as alcohols have almost similar properties as that of petrol engines. To get high efficiency and less pollutant, many engine designs were made, but no engine design change is required with minor blends of petrol with ethyl alcohol/methyl alcohol. To reduce the pollutants, catalytic converters with inexpensive catalysts are used.

Alcohols both ethyl alcohol and methyl alcohol are important substitutes for gasoline fuel as their properties are comparable and in particular their octane numbers are more than 100. However, ethanol is preferred to methanol, as its octane number is comparable to methanol, which determines the quality of combustion in spark ignition engine.

Moreover, its calorific value is higher than that of methanol. Engine modification is not necessary if they are blended with gasoline in small quantities. Investigations were carried out on conventional spark ignition engine with alcohols (methanol and ethanol) blended with gasoline (Rodrigo *et al.,* 2010; Maher *et al.*, 2011; Ahmet Necati Ozsezen *et al.,* 2011; Tangka *et al.,* 2011; Ibrahim Thamer Nazzal, 2011; Aakko-Saksa *et al.,* 2011; Heywood, 1988). It was reported that carbon monoxide (CO) and un-burnt hydrocarbons (UBHC) emissions decreased by 20% when compared with pure gasoline operation on conventional engine.

Thermal efficiency and fuel economy of the two-stroke engines are poor, and total emissions (TE) are very high when compared with four-stroke engines. However, in comparison to the four-stroke engines, the nitrous oxide (NO_x) emissions are low and CO emissions are equal (Nedunchezhian *et al.,* 2002).

The use of a catalytic surface to enhance chemical reaction rates is a well-established and common practice. Copper is a good conductor of heat, it enhances the combustion process by increased rate of pre-flame reactions and combustion flame stabilization. Copper coating of thickness 300 microns was provided on piston crown and inside portion of cylinder head, which improved engine performance and reduced pollutants of CO and UBHC (Murali Krishna *et al.,* 2008; Murali Krishna *et al.,* 2010.a; Murali Krishna *et al.*, 2010b; Narasimha Kumar *et al.*, 2011).

CO and UBHC, major exhaust pollutants formed due to incomplete combustion of fuel and quenching of the fuel-air mixture in the crevices of piston. Inhaling of these pollutants causes asthma, bronchitis, emphysema, slowing down of reflexes, vomiting sensation, dizziness, drowsiness and severe headache. Such pollutants also cause detrimental effects on animal and plant life, besides environmental disorders (Fulekar, 2004; Sharma, 2012; Khopkar, 2012) Driving methodology, road layout, traffic density, traffic condition, age and maintenance of the vehicle were some of the reasons for the formation of pollutants (Fulekar, 2004; Sharma, 2012; Khopkar, 2012).

Little literature was reported on comparative studies on reduction of pollutants with gasohol operation on copper coated spark ignition engine. An attempt was made here in this direction. Results were compared with data of gasoline operation on conventional engine.

Materials and Methods

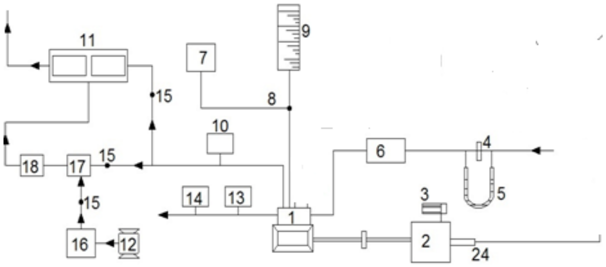
Fabrication of Copper Coated Combustion Chamber

In catalytic coated engine, piston crown and inner surface of cylinder head were coated with copper by flame spray gun. 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 (A trade name) flame spray gun. The coating has very high bond strength and does not wear off even after 50 h of operation (Nedunchezhian *et al.*, 2002).

Experimental Program of Four Stroke Copper Coated Spark Ignition Engine

Figure 1 shows the schematic diagram of experimental set-up used for investigations. It is a four-stroke, variable speed (2200-3000 rpm), variable compression ratio (3:1-9:1), single-cylinder, water-cooled, spark ignition engine (SI) engine (1). [1(brake power 2.2 kW, at the speed 3000 rpm) was coupled to an eddy current dynamometer (2) for measuring its brake power. Dynamometer was loaded by a loading rheostat (3). The accuracy of engine load was ±0.2kW. The bore of the engine was 70 mm while the stroke was 66 mm. Compression ratio of engine was varied with change of clearance volume by adjustment of cylinder head, threaded to cylinder of the engine. Brake power at different percentages of load was calculated by knowing the values of the output signals (voltmeter reading and ammeter reading) of dynamometer and speed of the engine. The accuracies obtained with measurement of output signals of dynamometer were within the limits. The speed of the engine was measured with digital tachometer with accuracy ±10 rpm. Percentage error obtained with measurement of fuel flow rate assuming laminar film in the burette was within the limit.

Air-consumption of the engine was obtained with an aid of air box, orifice flow meter and U-tube water manometer assembly. By means of orifice flow meter (4), U-tube water manometer (5) discharge of air was calculated, from which mass flow rate of air was calculated. Air box (6) was provided to to damp out the pulsations produced by the engine, for ensuring a steady flow of air through the intake manifold educe pressure pulsation at the inlet manifold of the engine. Fuel tank (7) was provided to store the fuel, while three way valve (8) was used to send the fuel from burette to engine.



1. Engine 2. Eddy current dynamometer, 3. Rheostat for loading, 4. Orifice meter 5. U-tube manometer 6. Air box 7. Fuel tank 8. Three-way valve, 9. Burette, 10. Sensor for measuring EGT 11. Analyzer for CO 12. Air compressor 13. Sensor for coolant outlet temperature, 14. Flow analyzer for coolant 15. Ball valve 16. Rotameter 17. Chamber for air of oxidizing chamber, 18. Oxidizing chamber, 19. Filter, 20. Rotameter 21. Heating element 22. Solution of DNPH container 23. Pressure transducer, 24. TDC encoder, 25. Console 26. Computer and 27. Printer

Fig. 1. Schematic diagram of the experimental work

Burette (9) was provided to measure flow rate of fuel. Percentage error obtained with measurement of difference of water levels in U-tube water manometer assuming laminar film in the manometer was within the limit. Sensor (10) was provided to determine exhaust gas temperature. Multi gas analyzer (11) was equipped in the system to determine CO, UBHC and NO_x at different values of BMEP of the engine. Air compressor (12) of capacity 1.0 HP. 3000 RPM was used to inject air flow rate (6 l/min) into the air chamber of catalytic converter. Outlet temperature water temperature was indicated by sensor (13). Water flow rate was determined by water flow meter (14). The accuracies of analogue temperature indicators were ±1%. Directional valves (15) were provided in the circuit for different operating conditions.

Results and Discussion

The optimum spark plug timing was obtained at 28^{o}bTDC with CE with neat gasoline operation and ethanol blended operation of gasoline, while it was 27^{o}bTDC with CCE with gasoline. Optimum ignition timing (OIT) is the timing at which maximum BTE is obtained.

Carbon Monoxide Emissions

Fig. 3 shows variation of CO levels with BMEP at RIT. Incomplete combustion is the main source of CO levels. From Figure-6.14, it is evident that CO levels increased at near full load and decreased at 80% of the full load and hiked again at full load with varieties of the engine with fuels. Engine requires a rich mixture at starting or at idling, as this is a common trend observed in SI engines. Hence CO emissions were found to be higher at no load or idling with varieties of the engine with fuels. The thermal efficiency of the engine was higher at 80% of the load. Hence CO emissions were found to be lower at 80% of the load owing to improved combustion. Engine requires a rich mixture at full load, as this is a common trend observed in SI engines. Hence CO levels were found to be higher at full loads. Gasohol reduced CO levels than petrol at every load with varieties of the engine. Combustion improved with gasohol owing to its number of high Octane

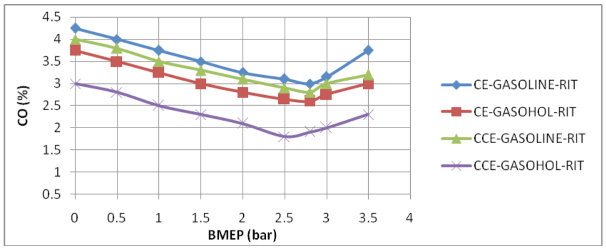


Fig. 3. Variation of CO with BMEP at RIT

The value of C/H (C= Number of carbon atoms, H=Number of hydrogen atoms in molecular composition of fuel) is less for gasohol than gasoline. Lesser this value, higher number of hydrogen molecules hence higher number of water vapour molecules (H_2O) in the exhaust of the engine. The volatility of gasohol is higher than that of gasoline leading to improved combustion and reduced CO emissions. CCE decreased CO emissions than CE with fuels owing to improvement in combustion with reaction of catalytic in nature.

Figure 4 shows variation of CO levels with brake mean effective pressure (BMEP) at an optimum ignition timing (OIT). From Figure 4, it is evident that there was elimination of fuel-cracking reactions with C_2H_5OH reaction, causing reduction of CO levels with C_2H_5OH in relation to operation of petrol. The exhaust with C_2H_5OH as fuel has more amount of water vapour than CO_2, as C_2H_5OH has lower value of C/H ratio 0.33 while 0.44 with operation of petrol. The presence of O_2 in the molecular composition of C_2H_5OH is also responsible for improvement in combustion and reduction of CO levels. Hydrogen is formed in the combustion of C_2H_5OH leading to improved increase of velocity of combustion and burning of air fuel mixture vigorously so as to minimize the formation of CO. There was a decrease of CO emissions with CCE in relation to CE with fuels. Copper, includes reactions of pre-flame causing improvement of combustion and elimination of emissions of CO.

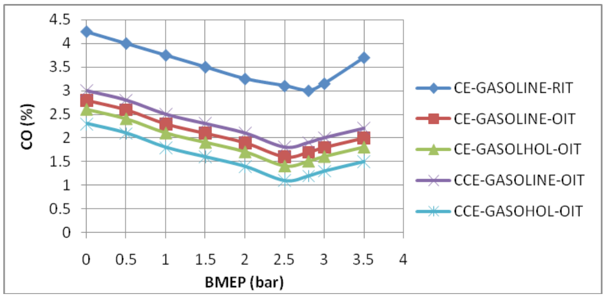


Fig. 4. Variation of CO with BMEP at OIT

Figure 5, presents bar chart showing the variation of CO levels at full load with varieties of the engine at RIT and OIT at a ratio of compression 9:1 and speed of 3000 RPM.

Case 1. Test fuel is same, configurations of the engine are different

From Figure 5, it is evident that CCE with operation of petrol decreases CO emissions at full load by 19% at RIT and 10% at OIT w.r.t CE with petrol operation. CCE with of operation gasohol decreased CO emissions at full load by 23% at RIT and 17% at OIT w.r.t CE with operation of gasohol.

Case 2. Configuration of the engine is same, test fuels are different

From Figure-5, it is noted that gasohol with CE operation decreased CO levels at full-load by 19% at RIT and 10% at OIT w.r.t petrol operation on CE. CCE with gasohol operation decreased CO levels at full- load by 23% at RIT and 31.8% at OIT w.r.t CCE with gasoline operation.

Case 3. Effect of ignition timing

From the same Figure-5, it is observed that there was a decrease of CO levels with timing of spark plug ignition because of more availability of O_2 to react with fuel and more resident time of O_2 with the fuel leading to improvement in combustion, causing reduction of CO.

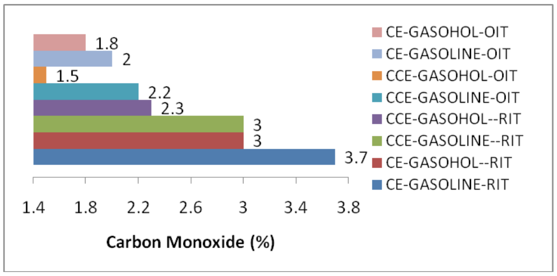


Fig. 5. Bar chart - variation of CO levels at full load

Unburnt Hydrocarbons

The variation of UBHC with BMEP with varieties of engine with fuels is depicted in Figure 6. There were similar trends of UBHC levels as those of CO levels with both varieties of the engine with fuels. UBHC emissions formed owing to incomplete combustion of fuel and accumulation of fuel in crevice volume. Like CO emissions, UBHC levels were found to be maximum at no load and partial load and lower at near full load and again higher at full load operation. The fuel which is un-burnt due to non-availability of oxygen will settle in crevice volume of the rings of the piston and walls of combustion chamber will not participate in reactions of the combustion as these parts are subjected to the lower temperature will be converted into UBHC levels in the engine's exhaust. Gasohol reduced UBHC levels than operation of petrol on both varieties of the engine at every load, owing to its number of high Octane and presence of O_2 in the composition of structure, which is a supporter of combustion. CCE reduced UBHC emissions than CE at all loads with fuels, owing to improvement in combustion due to improved flame velocity and pre-flame reactions. Fig. 6 shows the variation of UBHC with BMEP at recommended injection timing with both versions of the engine.

There were similar trends of UBHC levels as those of CO levels with both varieties of the engine with fuels. UBHC emissions formed owing to in-

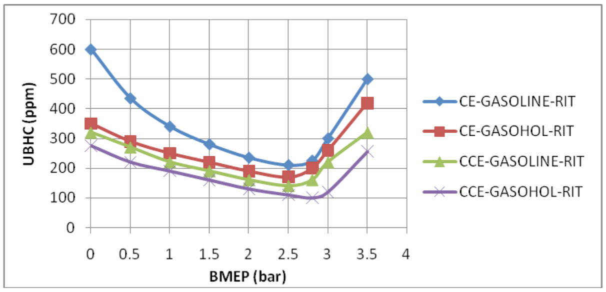


Fig. 6. Variation of UBHC with BMEP at RIT

complete combustion of fuel and accumulation of fuel in crevice volume. Like CO emissions, UBHC levels were found to be maximum at no load and partial load and lower at near full load and again higher at full load operation. The fuel which is unburnt due to non-availability of oxygen will settle in crevice volume of the rings of the piston and walls of combustion chamber will not participate in reactions of the combustion as these parts are subjected to the lower temperature will be converted into UBHC levels in the engine's exhaust. Gasohol reduced UBHC levels than operation of petrol on both varieties of the engine at every load, owing to its number of high Octane and presence of O_2 in the composition of structure, which is a supporter of combustion. CCE reduced UBHC emissions than CE at all loads with fuels, owing to improvement in combustion due to improved flame velocity and pre-flame reactions.

Figure 7 depicts variation of UBHC with BMEP at OIT   From Figure 7, it is evident that in both varieties of engines, UBHC levels behaved similar trends as those of CO levels. CCE decreased UBHC emissions as there is effect of flame speed with activity of catalytic in nature of CCE in relation to CE.

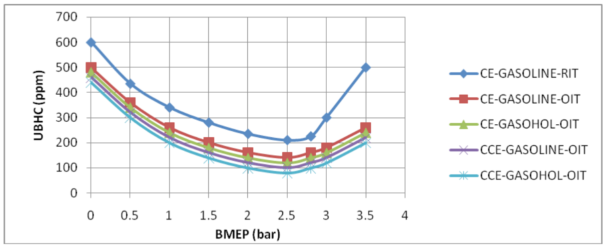


Fig. 7. Variation of UBHC with BMEP at OIT

Figure 8 presents a bar chart showing the variation of UBHC at full load at RIT and OIT with fuels at a ratio of compression 9:1 and speed of 50 rps.

Case 1. Test fuel is same, configurations of the engine are different

From Figure-8, it is evident that operation of gasoline with CCE decreased UBHC emissions at full load by 36% at RIT and 15% at OIT w.r.t CE with gasoline operation. Operation of gasohol with CCE decreased UBHC emissions at full load by 39% at RIT and 16% at OIT w.r.t CE with operation of gasohol. CCE improved combustion with pronounced activity of copper. Thermal conductivity of cuprum is very high, leading to improvement in combustion and causing reduction of crevice volume and hence UBHC emissions.

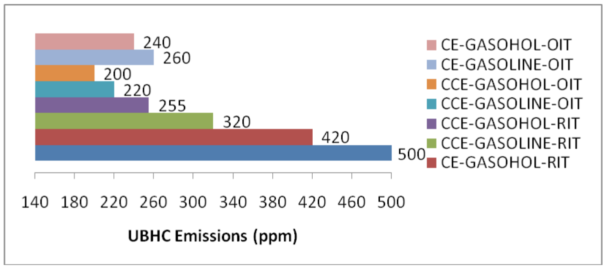


Fig. 8. Bar chart showing variation of UBHC at full load

Case 2. Configuration is same; test fuels of the engine are different

From Figure 8, it is clear that, CE with gasohol operation decreased UBHC levels at full load by 16% at RIT and 8% at OIT w.r.t neat petrol operation on CE.CCE with gasohol operation decreased UBHC levels at full load by 20% at RIT and 9% at OIT w.r.t CCE with gasoline operation. Gasohol has a high octane number with which combustion improves causing reduction of UBHC emissions in relation to operation of petrol. Ethanol has oxygen in its composition, which helps in combustion thus decreasing crevice volume and hence UBHC emissions.

Case 3. Effect of ignition timing

From the same Figure 8, it is observed that UBHC levels followed the close aspects as those of CO levels in both varieties of engine with fuels. Hike of duration of combustion and complete utilization of oxygen improved combustion and thus reducing crevice volume and hence UBHC emissions. Table 1 shows data of pollutant levels at full load operation of parental engine and CCE with fuels at a ratio of compression 9:1 and speed of 50 rps.

NO_x Levels

Fig. 9 Shows variation of NO_x levels with BMEP at RIT.

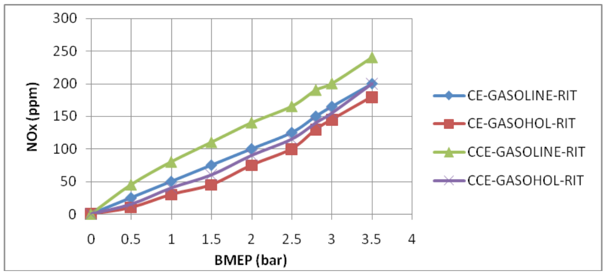


Fig. 9. Variation of NO_x with BMEP at RIT

NO_x levels in IC engines are formed due to availability of oxygen and temperature. NO_x levels increased with a hike of load with both varieties of the engine with fuel owing to the hike of mass of fuel consumed and hence combustion temperatures. Gasohol reduced NO_x levels than operation of petrol on both varieties of the engine. Owing to high heat of evaporation of C_2H_5OH, combustion temperature was absorbed. Therefore NO_x levels were lower with gasohol operation in relation to operation of petrol. CCE hiked NO_x levels marginally than CE at every load with both varieties of the engine as combustion temperatures increased with increased pre-flame reactions and improved flame velocity with catalytic action of CCE.

Fig.9 shows variation of NO_x levels with BMEP at OIT.

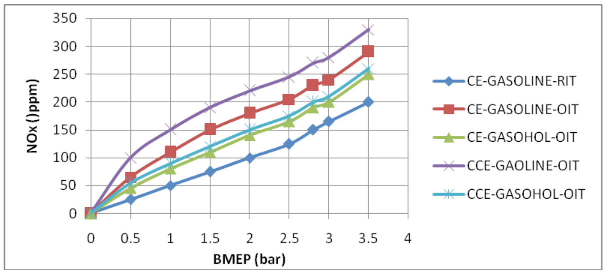


Fig. 9. Variation of NO_x with BMEP at OIT

CCE marginally increased NO_x emissions with gasoline operation at recommended ignition timing, as the combustion chamber was more hot. With advanced ignition timing, NO_x emissions increased with varieties of the engine with both fuels. Many researchers confirmed this trend with CE with petrol as fuel with an increase of resident time and gas temperatures. When spark plug timing was advanced, maximum heat release at full load during combustion increased, which confirmed the trend of NO_x emissions with advanced ignition timing. Figure 10 presents a bar chart showing the NO_x levels at full load at RIT and OIT with test fuels at a ratio of compression 9:1 and speed of 50 rps.

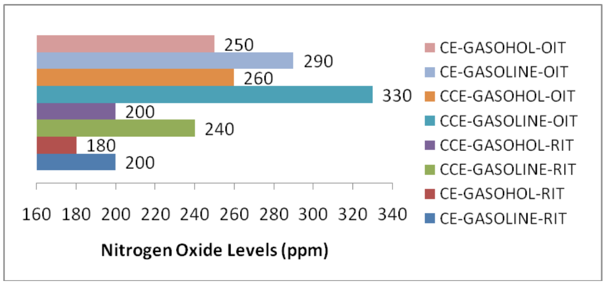


Fig. 10. Bar chart - the variation of nitrogen oxide levels

Case 1. Test fuel is same; configurations of the engine are different

From Figure 10, it is noted CCE with gasoline operation increased NO_x emissions at full load by 20% at RIT and 14% at OIT in relation to CE with gasoline operation. CCE with gasohol increased NO_x emissions at full load by 11% at RIT and 4% at OIT in relation to CE with gasohol operation. However, CCE marginally increased NO_x emissions with gasoline operation at RIT, as combustion chamber was more hot but gasoline blended with ethanol reduced overall NO_x levels effectively in comparison with neat gasoline owing to high vaporization of heat of C_2H_5OH, reduced combustion temperatures causing reduction of NO_x levels.

Case 2. Configuration is same; test fuels of the engine are different

From Figure 10, it is noted that CE with gasohol operation decreased NO_x emissions at full load by 10% at RIT and 10% at OIT in comparison with neat gasoline operation. CCE with gasohol decreased NO_x emissions at full load by 17% at recommended injection timing and 21% at optimum injection timing when compared with CCE with gasoline operation. However, CCE marginally increased NO_x emissions with gasoline operation at recommended ignition timing, as combustion chamber was more hot but gasoline blended with ethanol reduced overall NO_x levels effectively in comparison with neat gasoline owing to its high latent heat of vaporization of C_2H_5OH, causing reduction of combustion temperatures giving rise to decrease of NO_x levels.

Case 3. Effect of ignition timing

From Figure 10, it is noted that with advanced ignition timing, NO_x emissions increased with varieties of the engine with both fuels. Owing to hike of resident timing and more availability of O_2 leading to increase of combustion temperatures and hence NO_x emissions.

Conclusoin

1. The optimum ignition timing for copper coated engine was 27^{o}bTDC (before top dead centre), while it was 28^{o}bTDC with conventional engine.
2. The Emissions of CO, UBHC decreased by 20%

with copper coated combustion chamber when compared with conventional engine with test fuels.

3. The emissions of NO_x increased by copper coated engine with respect to conventional engine with gasoline operation.

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