Performance and emissions characteristics of Glow Plug Hot Surface Ignition C.I. Engine Using Ethanol as Fuel with Additives

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Abstract:

An IC engines 40 percentage of fuel input energy was converted into useful work and 60 percentage has been lost through exhaust gas and cooling system. In this research paper has been focused on the reduction of diesel engine emissions. The goal of this study was to evaluate performance and emission characteristics of ceramic coated hot surface ignition CI engine using ethanol-diesel as fuel with additive. In this investigation the different ignition improving additives like Iso amyl nitrate, Methyl Nitrate, Ethyl Nitrate, Butyl Nitrate and Cyclo Pentyl nitrate are consider as additives. The investigation was carried out by ethanol-diesel blended fuel with 5% of additive. The fuel additive reduces the smoke density of the engine exhaust. In this present work the performance parameters of Power and Mechanical efficiency, Fuel – air ratio, Volumetric efficiency, Specific fuel consumption or Brake Specific fuel consumption, Specific output, Thermal efficiency Exhaust smoke and other emissions of hydro carbon(HC), Carbon monoxide (CO), carbon dioxide (CO_2), Nitrogen oxide (NOx) and exhaust gas temperature, Effective pressure and Torque and Smoke density are evaluated. The copper piston with glow plug hot surface ignition engine with Iso amyl nitrate additive give the best result among other additives of copper piston crown materials. It is concluded that among the five additives tested to the copper piston crown material GHSI engine with ethanol as fuel, Iso amyl nitrate gives the best results. Brake thermal efficiency percentage improvement for the copper piston crown material GHSI engine with Iso amyl nitrate over the normal GHSI engine is 32.98% at rated load. This is due to the positive ignition of the injected Ethanol spray under all conditions. The single cylinder, four strokes 5.2kW Kirloskar, water cooled DI diesel engine with a bore of 87.5 mm and stroke of 110 mm and a compression ratio of 17:1 is used for the experimental work.

Key word: Ethanol; Glow plug hot surface ignition Engine; additives; emissions

1. INTRODUCTION

It is apparent from the increasing popularity of light-duty diesel engines that alternative fuels, such as alcohols, must be applicable to diesel combustion if they are to contribute significantly as substitutes for petroleum based fuels. Although replacing diesel fuel entirely by alcohols is very difficult, an increased interest has emerged for the use of alcohols, and particularly lower alcohols (methanol and ethanol) with different amounts and different techniques in diesel engines as a dual fuel operation during the recent years. Ethanol is one of the possible fuel for diesel replacement in CI engines [1]. It can be made from raw materials such as sugarcane, sorghum, corn, barley, cassava, sugar beets etc. A biomass based renewable fuel, ethanol has cleaner burning characteristics, and a high octane rating. The application of ethanol as a supplementary compression-ignition fuel may reduce environmental pollution, strengthen agricultural economy, create job opportunities, reduce diesel fuel requirements and thus contribute in conserving a major commercial energy source [2]. A surface ignition ceramic heater [3] CI engine is able to operate at higher temperature enabling combustion of fuel at complete resulting to increase combustion efficiency. This should increase engine performance, decrease fuel consumption and reduce pollution [4]. Ceramic heater provides instant heat within seconds of turning, which helps save fuel and reduce emissions. It is mounted through the engine head,that heats up and warms air moved over its surface, due to its inherent self-regulating characteristics. Ceramic heater for diesel combustion would represent a simple low cost and easy approach in diesel engine performance [5].

In the C.I engines a premixed fuel air vapor is drawn in during the suction stroke, a single high intense spark passes across the electrode, producing a core of flame from which the combustion spreads to the envelope of mixture surrounding it at a fast rate. The above two methods evidently show that the fuel properties of the first method will not be suitable for the second, and hence if we need to have an engine with multi fuel capability, the nature of combustion should be very different from the above methods. This is where the concept of surface ignition comes into active consideration. Surface ignition indicates the beginning of combustion from a hot surface. It will be interesting to know that almost all fuels exhibit this property to varying degrees, the alcohols being highly susceptible to this kind of combustion [8].

2. Experimental work

The single cylinder, four strokes 5.2kW Kirloskar, water cooled DI diesel engine with a bore of 87.5 mm and stroke of 110 mm and a compression ratio of 17:1 is used for the experiment(8,9). The engine load is applied with eddy current dynamometer. For the reduction of heat to the cooling water. Then the existing aluminum piston is replaced by a copper piston crown GHSI Engine. These tests are conducted with Ethanol as fuel in GHSI engines as usual. The experiments are carried out on the plain engine with the copper piston crown material with additive on GHSI engine using Ethanol as fuel to determine the performance, emissions and the combustion parameters. In this investigation the different ignition improving additives like Iso amyl nitrate, Methyl Nitrate, Ethyl Nitrate, Butyl Nitrate and Cyclo Pentyl nitrate are consider as additives. The investigation was carried out by ethanol-diesel blended fuel with 5% of additive. The fuel additive reduces the smoke density of the engine exhaust. In this present work the performance parameters of Power and Mechanical efficiency, Fuel – air ratio, Volumetric efficiency, Specific fuel consumption or Brake Specific fuel consumption, Specific output, Thermal efficiency Exhaust smoke and other emissions of hydro carbon(HC), Carbon monoxide (CO), carbon dioxide (CO_2), Nitrogen oxide (NOx) and exhaust gas temperature, Effective pressure and Torque and Smoke density are evaluated.

Heat transfer affects engine performance, efficiency, and emissions. The mass of fuel within the cylinder, higher heat transfer to the combustion chamber walls, will lower the average combustion gas temperature and pressure, and reduce the work per cycle transferred to the piston. Thus specific power and efficiency are affected by the magnitude of engine heat transfer [8]. Advances in engine technology by introducing ceramic heater increase the engine output efficiency and reduce the emission parameters [10]

Figure 1: Experimental setup of GHSI Engine Test rig

3. Results and discussions

3.1 Brake Thermal Efficiency

The variation of brake thermal efficiency with brake power out for five additives for copper piston crown material Glow plug hot surface ignition engine is shown in the figure.

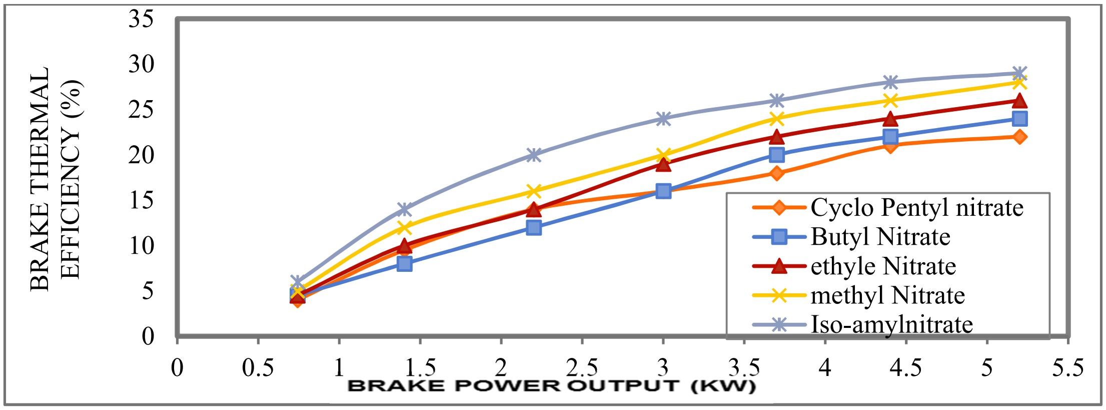

Figure 2: Variation of Brake thermal efficiency with power output for Ethanol (with additives) operation in best Glow plug hot surface ignition engine

The variation of brake thermal efficiency with brake power out for five additives for copper piston crown material Glow plug hot surface ignition engine is shown in the figure 2. it is observed that maximum efficiency over a wide range of operation, particularly at higher loads is shown by copper piston crown material Glow plug hot surface ignition engine with Iso amyl nitrate as an additive.

3.2 Brake Specific Fuel Consumption

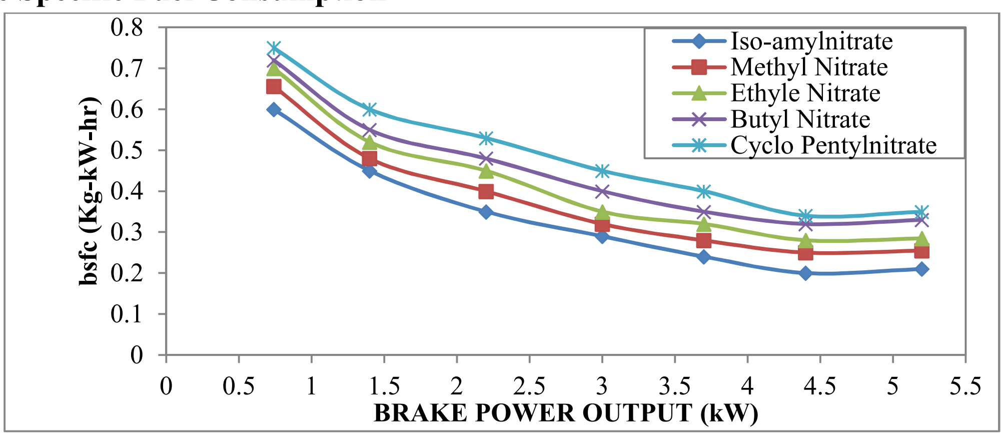

Figure 3: Variation of Brake Specific fuel consumption with power output for Ethanol (with additives) operation in best Glow plug hot surface ignition engine

The variation of bsfc with power output is illustrated in figure 3. All the configurations have normal GHSI brake specific fuel consumption compared to base engine. The Copper gives lower bsfc 0.58 kg-kW-hr over wide range of operation. The brake specific fuel consumption principally depends upon the consistent mixture formation and complete combustion of the fuel. With the better vaporization of the fuel, the charge becomes homogeneous and the combustion of fuel can be improved. The heat within the combustion chamber will increase and the combustion potency is improved.

3.3 Volumetric Efficiency

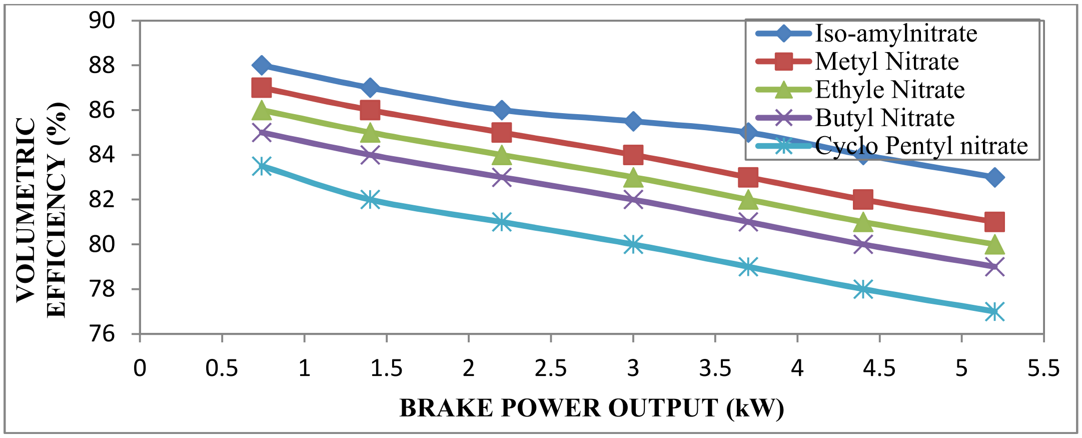

Figure 4: Variation of Volumetric efficiency with power output for Ethanol (with additives) operation in best Glow plug hot surface ignition engine

The variation of volumetric efficiency with power output is illustrated in figure 4. The general trend is that the volumetric efficiency drops with increase in power output. At standard condition, the volumetric efficiency varies from 88% at no load to 85% at full load. With copper configuration the volumetric efficiency comes to 84% at no load and to 74% at full load.

3.4 Hydrocarbons

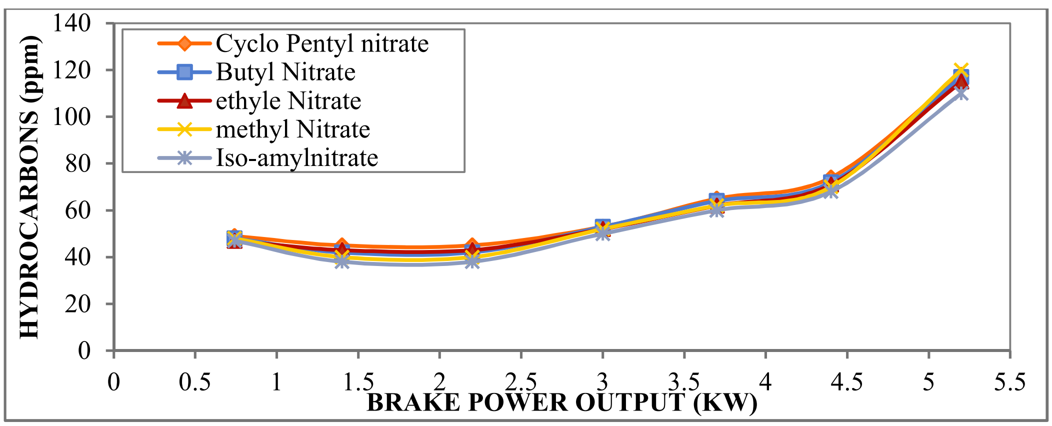

Figure 5: Variation of Hydrocarbon emissions with power output for Ethanol(with additives) operation in best Glow plug hot surface ignition engine

Figure 5: shows he various hydrocarbon emission levels for the copper piston crown material Glow plug hot surface ignition engine with different selected additives with brake power output. A reduction in hydrocarbon level has been observed with all additives with copper piston crown material Glow plug hot surface ignition engine. Copper piston crown material Glow plug hot surface ignition engine with iso amyl nitrate as an additive is observed to show a maximum reduction in hydrocarbon emissions and is about395ppm at rated load compared to copper piston

crown material Glow plug hot surface ignition engine with Iso amyl mnitrate and Cyclo Pentyl Nitrate as an additives. There will be a reduction in the level of hydrocarbon emissions with the addition of additives to copper piston crown material Glow plug hot surface ignition engine.

3.5 Carbon dioxide Emission

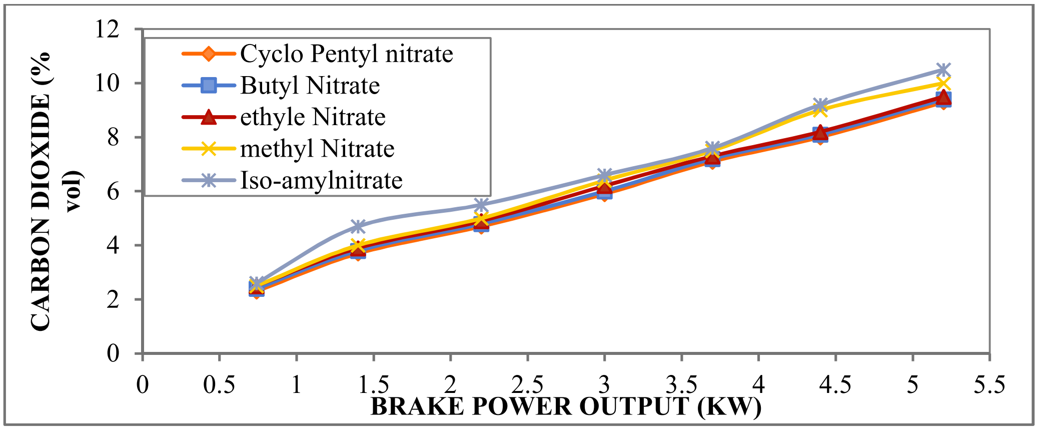

Figure 6: Variation of Carbon Dioxide Emissions with power output for Ethanol (with additives) operation in best Glow plug hot surface ignition engine

The variation of Carbon dioxide emissions with power output is illustrated in figure 6. Because of better and complete combustion in the insulated engines, Carbon dioxide levels are higher for insulated engines. It indicates that the level of Carbon dioxide in the exhaust is highest for Copper piston crown configuration. Higher Carbon dioxide in the exhaust is an indication of complete or better combustion.

3.6 Carbon Monoxide Emission

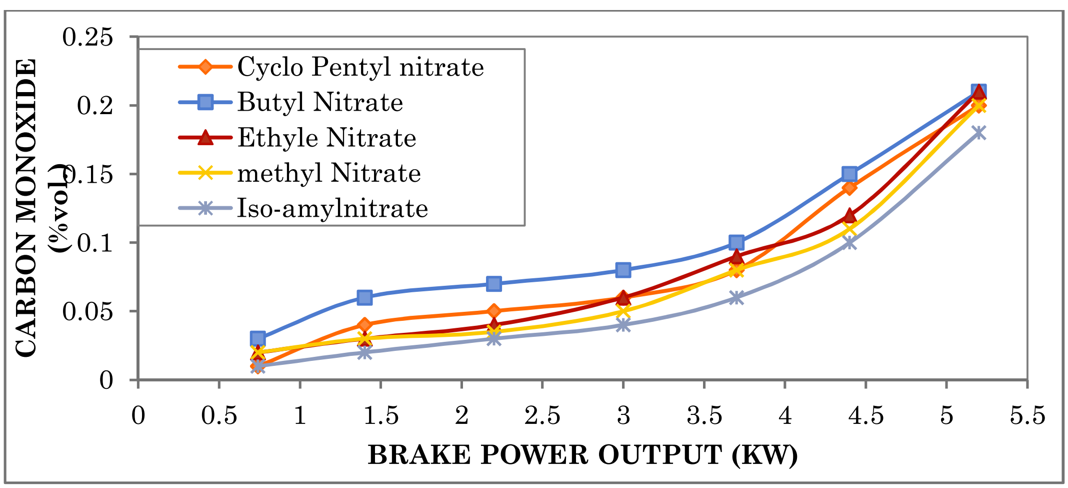

Figure 7: Variation of Carbon Monoxide emissions with power output for Ethanol (with additives) operation in best Glow plug hot surface ignition engine

The variation of the carbon monoxide levels with brake power output five additives of a copper piston crown material Glow plug hot surface ignition engine is shown in figure 7. The combustion in the copper piston crown material Glow plug hot surface ignition engine with additives is more complex and the oxidation of the carbon monoxide is also improved due to the higher combustion chamber temperatures. The lowest carbon monoxide emission is given by engine with copper piston crown material Glow plug hot surface ignition engine, with Iso amyl nitrate as an additive and the highest carbon monoxide emission is given by engine with copper piston crown material Glow plug hot surface ignition engine with Cyclo Pentyl Nitrate as an additive.

3.7 Nitrogen Oxide Emissions

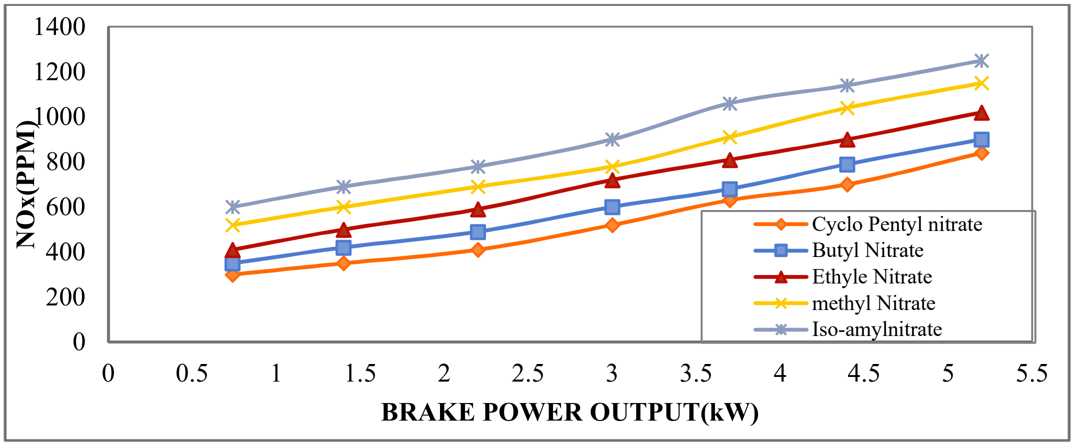

Figure 8: Variation of Nitrogen Oxide Emissions with power output for Ethanol (with additives) operation in best Glow plug hot surface ignition engine

The variation of Nitrogen oxide emissions with power output is illustrated in figure 8. Because of better and complete combustion in the insulated engines, Nitrogen oxide levels are higher for insulated engines. It indicates that the level of nitrogen oxide is highest for Copper GHSI configuration. Higher nitrogen oxide in the exhaust is an indication of complete or better combustion

3.8 Exhaust Gas Temperature

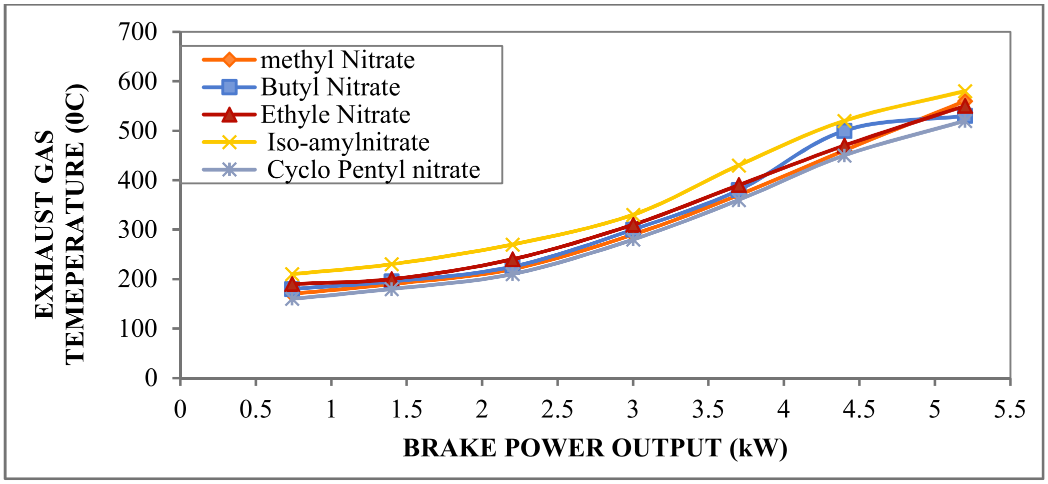

Figure 9: Variation of Exhaust gas Temperature with power output for Ethanol (with additives) operation in best Glow plug hot surface ignition engine

The variation of exhaust temperature with power output is illustrated in figure 9. It clearly indicates that with the degree of insulation increasing the exhaust gas temperature progressively increases. Exhaust temperatures increase with the engine load. Because of better insulation for the Copper GHSI configuration, the exhaust temperature is higher compared to all other configurations. There is a 212^0C rise in the exhaust temperature for this configurations compared to base engine.

3.9 Ignition Delay

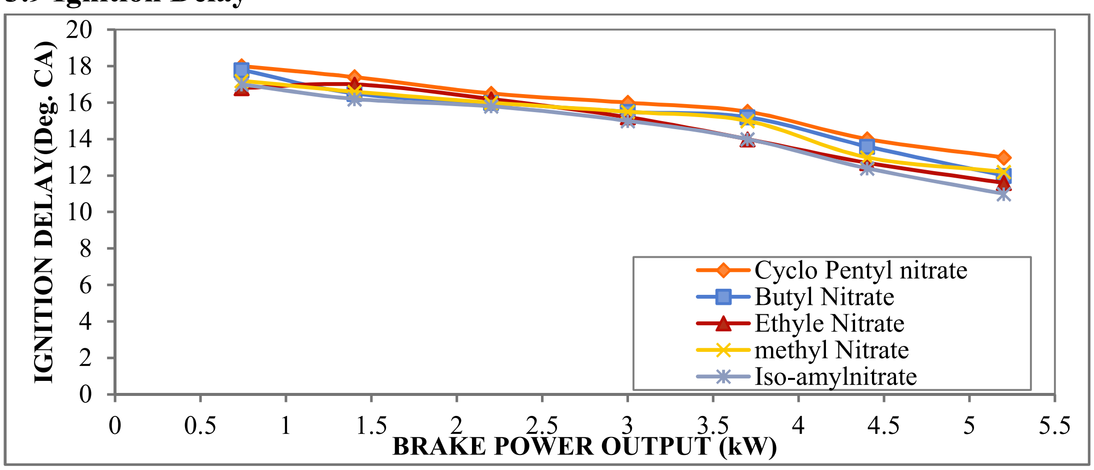

Figure 10: Variation of Ignation Delay with power output for Ethanol (with additives) operation in best Glow plug hot surface ignition engine

The variation of ignition delay period with brake power output for five additives of a copper piston crown material Glow plug hot surface ignition engine is indicated in the figure 10. The lowest ignition delay among all the additives tested is shown by the copper piston crown material Glow plug hot surface ignition engine with Iso amyl nitrate as an additive and the highest ignition delay is observed for copper coating Glow plug hot surface ignition engine with Cyclo Pentyl Nitrate as an additive.

3.10 Indicated Mean Effective Pressure

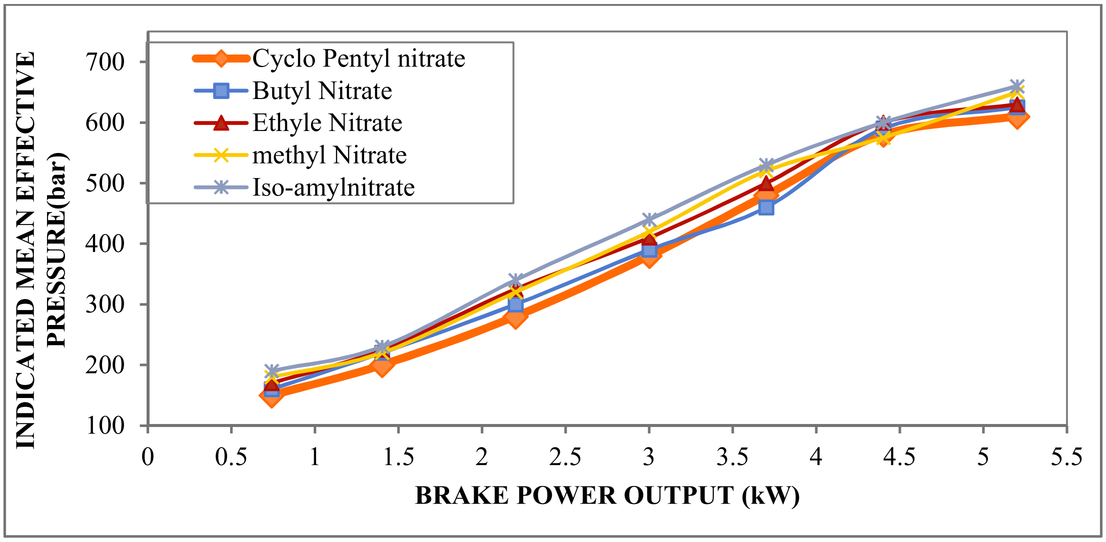

Figure 11: Variation of Indicate dMean Effective Pressure with power output for Ethanol (with additives) operation in best Glow plug hot surface ignition engine

The variation of indicated mean effective pressure with power output is illustrated in figure 11. The increase in the Indicated mean effective pressure is normally expected because of higher temperatures in these configurations. Highest Indicated mean effective pressure is obtained for the Copper GHSI configuration compared to other configurations. The increase in the Indicated mean effective pressure depends upon the level of insulation applied.

3.11 Peak Pressure

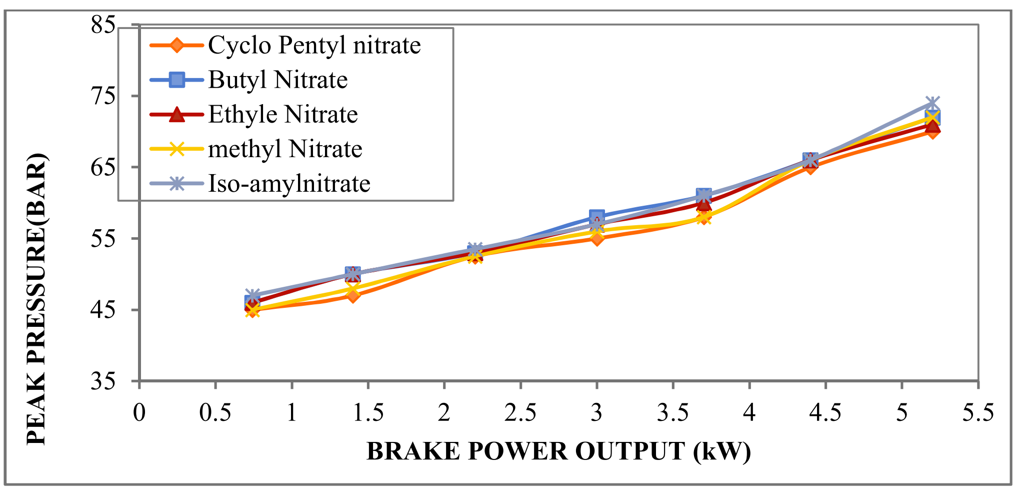

Figure 12: Variation of Peak Pressure with power output for Ethanol (with additives) operation in best Glow plug hot surface ignition engine

The variation of peak pressure with brake power output for five additives of a copper piston crown material Glow plug hot surface ignition engine is shown in the figure 12. At higher outputs particularly where the gas temperatures accelerate the combustion process, the peak pressure will increase with the addition of additives to the copper piston crown material Glow plug hot surface ignition engine. The peak pressure developed by copper piston crown material Glow plug hot surface ignition engine is found to be higher and about 72bar with Iso amyl nitrate as an additive and for copper coating Glow plug hot surface ignition engine with Cyclo Pentyl Nitrate as an additive, the peak pressure is lower and is about 65 bar.

3.12 Maximum Rate of Pressure Rise

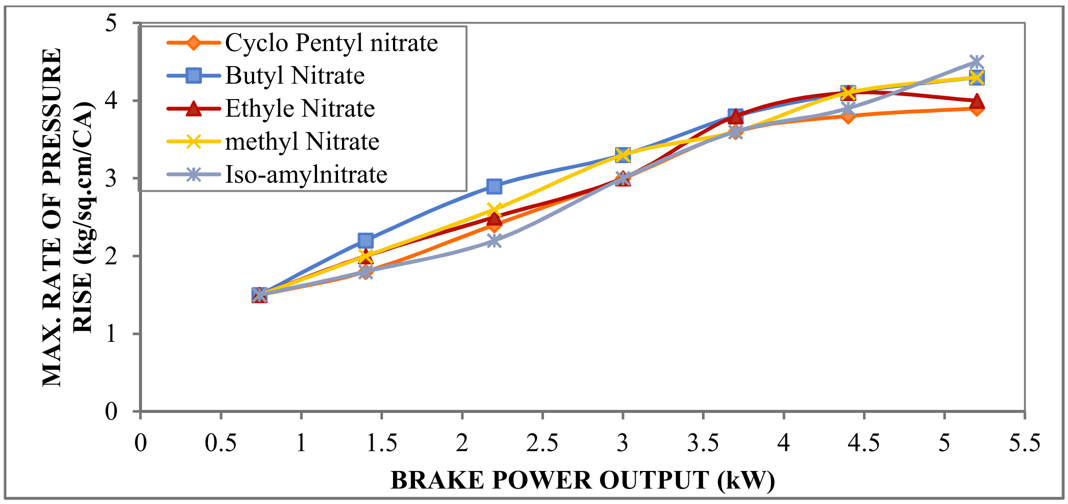

Figure 13: Variation of Maximum rate of pressure rise with power output for Ethanol (with additives) operation in best Glow plug hot surface ignition engine

The variation maximum rate of pressure rise with brake power out for five additives of a copper piston crown material Glow plug hot surface ignition engine is illustrated in figure 13. with the addition of different additives with copper piston crown material Glow plug hot surface ignition engine, the maximum rate of pressure rise has been observed to be higher. For the copper coating Glow plug hot surface ignition engine with Iso amyl nitrate as an additive it is highest and is about 25% by volume at rated load. Due to sluggish combustion there is a low ranges of pressure rise with alcohols fuel in the low output ranges. Particularly at higher outputs, the maximum rate of pressure rise is higher with additives, where the gas temperatures accelerate he combustion process.

3. CONCLUSIONS

The following conclusions are drawn with ethanol operating GHSI engine with different additives. It is concluded that among the five additives tested to the copper piston crown material GHSI engine with ethanol as fuel, Iso amyl nitrate gives the best results.

- Brake thermal efficiency percentage improvement for the copper piston crown material GHSI engine with Iso amyl nitrate over the normal GHSI engine is 32.98% at rated load. This is due to the positive ignition of the injected ethanol spray under all conditions.
- Copper piston crown material Glow plug hot surface ignition engine with Iso amyl nitrate gives lower bsfc (0.58 kg /kW-hr) over wide range of operation.
- The copper piston crown material GHSI engine, the volumetric efficiency comes to 85% at no load and to 75% at full load.
- The reduction in hydrocarbon emission level over the corresponding normal Glow plug hot surface ignition engine is about 118 ppm at rated load.
- The copper piston crown material GHSI engine with Iso amyl nitrate gives the lowest level of CO emissions as compared to other coatings and is about 12.5% by volume.
- It indicates that the level of Carbon dioxide in the exhaust is highest 115% for copper piston material Glow plug hot surface ignition engine.
- Nitrogen oxide levels are higher 788 ppm for different piston crown materials Glow plug hot surface ignition engines.

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