PERFORMANCE STUDY OF ALCOHOLS IN AN INSULATED FOUR STROKE DI DIESEL ENGINE WITH SWIRL COMBUSTION CHAMBER

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ABSTRACT

Stringent emission legislation all over the world has led to the search for alternative fuels for I.C. Engines. The major pollutants from a diesel engine are oxides of nitrogen (NOx), smoke and particulate matter. Concentration is very much focused on compression ignition engines because they have been recognized as the most ideal power plants in transportation, industrial and agricultural sectors, due to their high fuel efficiency. But their major disadvantage is the production of exhaust particulates which have to face increasingly stringent regulation. The difficulty in meeting the increasingly stringent limitations on particulate and NOx emissions has stimulated interest in ethanol-fueled compression ignition engines because it is a renewable bio-based resource and it is oxygenated, thereby providing the potential to reduce particulate emissions in compression–ignition engines and ethanol diffusion flames produce virtually no soot. Unfortunately ethanol does not have suitable ignition properties under typical diesel conditions because the temperatures and pressures characteristic of the diesel engines causes a longer ignition delay while using ethanol. Therefore, in order to make use of ethanol in a diesel engine, either a system to improve the ignition quality of ethanol or a system of some ignition aids is necessary. This paper describes the tendency of alcohols to ignite in a heated combustion chamber was made use of to achieve this end. Here a single cylinder 5 H.P diesel engine was used in which the fuel was sprayed at 165 bar due to alcohols lower viscosity and made to ignite in an insulted combustion chamber. Along with that a swirl combustion chamber design was adopted to obtain improvement in performance. This performance was evaluated under both constant speed and variable speed conditions. The effect of water content on alcohol performance and of insulation on diesel performance was studied. All the above investigations are useful and these results are expected to lead to a substantial contribution to the development of an Alcohol diesel engine.

Key words: Alcohols, ,ceramics, Insulated engines, Swirl combustion chamber

INTRODUCTION

The compression Ignition engines have most of the applications in fields of transportation, industry and agriculture due to their longer life, reliability and fuel economy. The phenomenal growth and unprecedented rise in their numbers have caused demand for the petroleum fuels and as a result in serious shortage of diesel fuels. It is therefore very essential to look for alternative fuels for the existing engines with minimum modifications with comparable efficiencies, power outputs and emission. Considering the above requirements one of the promising fuels is Alcohol because these are as liquids at atmosphere and can be easily transportable and are most convenient to use as fuels, particularly for the automotive applications. They have no sulphur, so there is no sulphur dioxide in the exhaust. Among alcohols, ethanol in the form of azeotropic product of distillation containing 4 to 6 % water is being given the utmost importance from its production point of view. The lower viscosity of alcohol affects the delivery characteristics of the pumping limiting the output of the pump. So it requires considerable modifications for the conventional diesel engines.

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USE OF ALCOHOLS IN I.C ENGINES

The alcohols, owing to their very high self-ignition temperatures cannot ignite in the existing CI engines whose compression ratios rarely exceed 20:1.Their poor ignition quality is reflected in their very low cetane numbers. And due to the high latent heats of vaporization of alcohols, excessively long delays are caused when they are injected in CI engines. In addition to these basic problems, Shipinski et al [14] have highlighted the fuel handling problems which may affect the performance of the fuel injection system and also the fuel properties like spray characteristics, ignition delay and rate and duration of the combustion. Finally he suggested that a VCR engine system holds out most promise for multi-fuel use.

Kamo and Bryzik **[5]** have demonstrated the use of Partially Stabilized Zirconium (PSZ) as the insulating material and also reported reduction in carbon monoxide, carbon particulates and smoke emission levels. Woshini et. Al [6] reported the performance of ceramic coated engine with PSZ to 7% improvement in fuel consumption and reduction in HC emissions due to premixed combustion. Wallace et **[7]** have reported the use of a thermal barrier piston in the adiabatic engine and developed the temperature distribution analysis and reported that the piston top temperature were higher by around 400^0C for the thermal barrier pistons. According to the Kobori et [8] the insulation in the combustion chamber decreases the premixed fraction and increases the diffusion phase of combustion. Sun et [9] argued that decrease in premixed combustion by 75% with the ceramic insulation increases the BSFC by 9%

The insulated high temperature components include piston, cylinder head, valves and cylinder liner. So the insulating materials used in the combustion chamber should have lower thermal conductivity, good mechanical strength and must capable of withstanding for higher temperatures [8,11]. With the insulation of the engine the exhaust energy is increased compared to that of the conventional engine. Therefore, more technical innovations must be developed to extract useful energy from the exhaust and to derive the maximum benefits from this insulated engine concept. Additional power and improved efficiency derived from an adiabatic engine will be possible because the energy lost to the cooling water and exhaust gas, can converted into useful power through the use of turbo machinery.

According to Pleeth et al [13] addition of ethanol to normal diesel improves the combustion efficiencies, reduce smoke emissions and the characteristics of diesel knock was eliminated and the black exhaust smoke changed to white. Nagalingam et al [8] have taken the advantage of igniting the alcohols in the swirl combustion chamber with alcohols as the sole fuel in a CI engine of the compression ratio as low as 9:1.

The main objective of the present work is to improve the performance of the alcohols with the swirl combustion chamber. Further it was desired to evaluate the emissions of the engine when running on alcohol and to ensure that these were tolerable. The most important part of the work is to prepare the insulated swirl combustion chamber.

INSULATED ENGINE COMPONENTS PREPARATION

For the development of the Insulated engine (IE) in the present investigations the coating material selected must withstand for higher temperature and should also have sufficient strength. Among all the coating materials searched the partially stabilized Zirconium (PSZ) is found to be quite useful for adiabatic engine application because of its excellent insulating characteristics, adequate strength and thermal expansion characteristics [2, 5, 6,]. The insulated engine developed is having an air gap piston and liner, PSZ coated cylinder head and valves. The coating thickness on the components was based on the theoretical analysis and recommendations made by Wong et al [13].The insulation methodology is explained in detail as follows.

Insulated Air Gap Piston

In this a 2 mm air-gap (whose thermal conductivity is low) is provided between a metallic crown and the standard piston made of Aluminum alloy. This air gap is optimized based on the literature available [10]. The metallic crown and standard piston were separated by copper and steel gaskets. Figure.1 shows the air gap insulated piston with brass insert.

Figure1: An air-gap insulated piston with brass insert

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Insulated Cylinder Head and valves

The combustion chamber area of the cylinder head and the bottom surfaces of the valves are machined to a depth of 0.5 mm and are coated with PSZ material for the same depth [3].The details of cylinder head and valves are as shown in the Fig 2.

Figure 2: PSZ coated cylinder head and valves

Insulated Cylinder Liner

A thin mild steel sleeve is circumscribed over the cast iron liner maintaining a 2mm layer of air in the annular space between the liner and the sleeve [10]. The joints of the sleeve are sealed to prevent seepage of cooling water into the air-gap region.

EXPERIMENTAL MEASUREMNETS

A stationary, four stroke, 3.68 Kw direct injection Kirloskar water cooled single cylinder diesel engine is used to conduct experiments. If the engine is operated at normal injection pressures the amount of alcohol injected (due to low viscosity) in to the engine will be more and further it may cool the engine due to its higher latent heat of vaporization. So the fuel injection pressure is reduced to 165 bar for the experiment. With the high self ignition temperature of alcohol it takes more time for the vaporization. So the injection timing is made advanced to 27^0 bTDC. All the tests are conducted at the rated speed of 1500 rpm [12]. The experimental set up used is as shown the following Figure.3.

Figure. 3. Experimental set up of Insulated Engine

For the exhaust gas temperature measurement, a calibrated Ni-Ni Cr thermocouple was used and voltage readings from a mill voltmeter were converted to ^{0}C. The thermocouple was positioned in the exhaust line immediately downstream of the exhaust port. The fuels used in the present work are ethanol and diesel. The level of the lubricating oil in the sump was checked periodically. Constant water flow was maintained through the engine to prevent overheating. All the readings were taken under steady running conditions.

EXPERIMENTAL INVESTIGATIONS

The diesel and alcohol fuels were run on Normal combustion chamber (NCC) and insulted Swirl Combustion chamber engines (SCC) and its performance studied at 1000 rpm and 1500 rpm.

RESULTS

The experimental investigations are carried out on normal combustion chamber and the swirl-combustion chamber with both diesel and alcohols and the processed results are presented in the form of graphs.

Ignition delays generally tended to decrease with increase in the load. Except at mid – load range at 1500 rpm, delays for diesel were longer than ethanol. Delays for both fuels were longer at the higher speed. At low loads at 1500 rpm, diesel ignition occurred very close to TDC. The increased turbulence at 1500 rpm in the swirl-chamber engine may have compensated the ignition delay for the ethanol. But for the diesel, the ignition delays are not that much.

Peak pressures were higher at 1000 rpm than 1500 rpm. Diesel showed high peak pressures at both speeds. Lowest values were obtained with ethanol at 1500 rpm. The longer ignition delays and the lower peak pressures and rates of pressure rise at higher speed clearly pointed to a slowing down of combustion with increasing speed.

Almost identical thermal efficiency curves were obtained for both ethanol and diesel at 1000 rpm. At 1500 rpm the curve for diesel was higher than for ethanol over the entire load range. Peak efficiencies for diesel and ethanol were 26.5 and 24.9 percent respectively, both at 1500 rpm.

Peak power on diesel at 1500 rpm in the original Kirloskar engine was 3.68 KW. In the present set-up peak power on diesel was around 2.82 KW only. At this point exhaust smoke was dense black because of poor air utilization. This is because of the non optimal shape of the combustion chamber.

The main purpose of this work is to prove that engine could be run on alcohols as sole fuels. So the combustion chamber was selected simple one only. Peak power output on ethanol at 1500 rpm was less than diesel, because ethanol is less dense and the calorific value is also half that of diesel. The very low outputs were also attributed to excessive wall-wetting.

It observed that poor fuel economy because of the odd combustion chamber shape, excessive wall-wetting caused by the very narrow cuboidal passage, throttling losses in the connecting passage and the drop in compression ratios. One entire side of the swirl chamber block was exposed to the atmosphere; this may further increase the heat losses.

Swirl combustion chamber engines involve expensive cylinder head construction. Heat losses to the walls are large and for the cold-starting, glow plugs have to be used. Thermal efficiencies are lower for swirl combustion chamber engines, due to the grater heat losses and also pressure losses in the narrow connecting passage. However, higher smoke-limited outputs may be achieved. The ignition delays are shorter than direct combustion chamber engines and are more suitable for high and variable speed operations.

With this combustion chamber the engines can be run smoothly because the chambers are contained in the stainless-steel inserts, absorbs the initial shock of the combustion, thus relieving the piston of extreme pressure variations. Finally the nozzles, with their self cleaning action, do not foul easily and require far less maintenance, which have very small openings and are thus susceptible to clogging. Exhaust gas temperatures were always higher in the swirl-chamber engine.

CONCLUSIONS

The following conclusions can be drawn from the processed results of the experimentation.

- With the normal compression ratio diesel engine the thermal efficiencies and the power outputs were low and the combustion slowed down with increase in speed.
- To avoid the draw backs of the normal engine swirl combustion chamber is employed, in which the engine operation was smooth and the combustion is also rapid than normal engine.
- The fuel economy and the peak outputs were poor due to excessive wetting of the combustion chamber walls. This can be reduced with swirl-chamber with wide passage holder which minimizes the wall wetting.
- Diesel knocked severely at low loads and speeds.
- Water content was found to delay ignition and increases the peak pressures for ethanol and this can be reduced with surface ignition in the same chamber.
- With increasing the injector opening pressure, the fuel economy can be increased up to 32 percent.
- The connecting passage diameter can be increased to reduce throttling losses.

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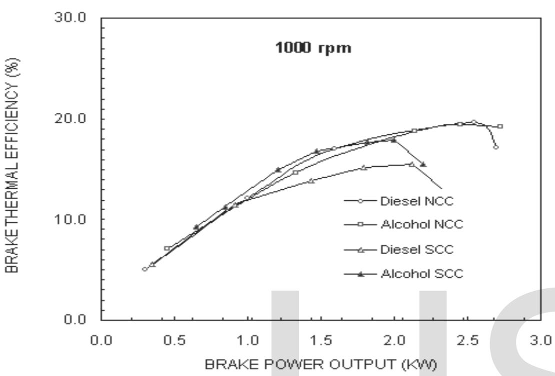


Fig.1 Comparison of brake thermal efficiency with power output

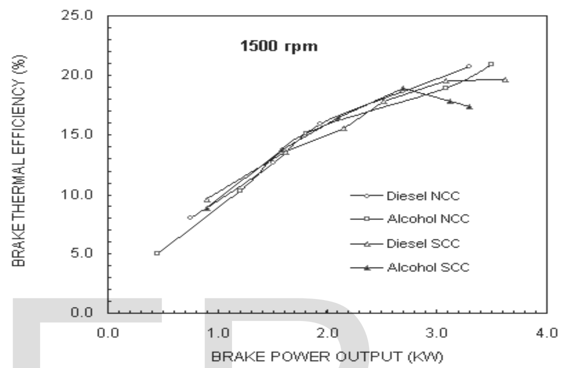
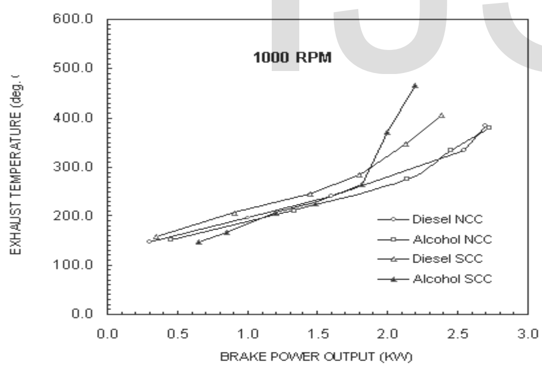
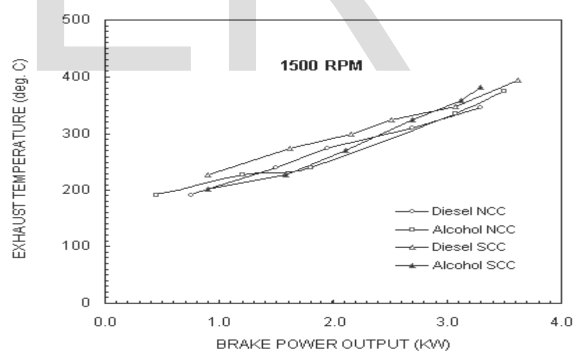


Fig.2 Comparison of brake thermal efficiency with power output





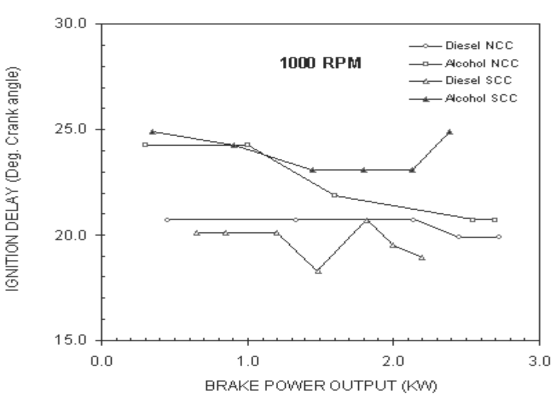


Fig.5 Comparison of Ignition delay with power output

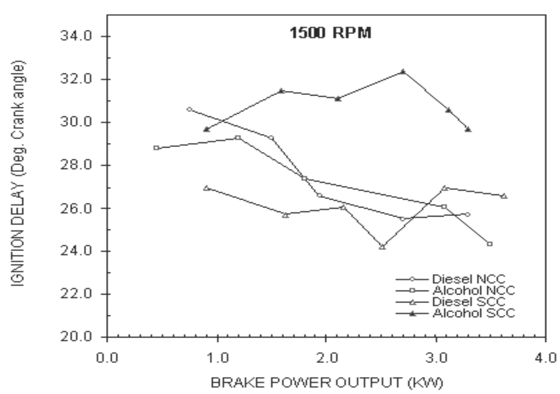


Fig.6 Comparison of Ignition delay with power output