INVESTIGATION ON FOUR STROKE CERAMIC HEATER SURFACE IGNITION C.I. ENGINE USING ETHANOL- DIESEL BLENDS WITH AMYL NITRATE ADDITIVE FOR 13.2 to 20.2 CR

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ABSTRACT

An experimental investigation on the performance of surface ignition four stroke C.I (Compression Ignition) engine fueled with pure diesel (0/100) and ethanol-diesel blends ratio of 15/85, 25/75, 30/70 and 35/65 by volume of ethanol are evaluated. Amyl nitrate (B) additive is used to satisfy mixture homogeneity and prevent phase separation. The mixing protocol considered of first blending the emulsifier into the ethanol and then blending this mixture into the diesel fuel. The tests are carried out on a ceramic heater surface ignition single cylinder aluminium oxide coating on piston head diesel engine under steady state operating conditions on two specified speeds of 1250 rpm and 1500 rpm. The stabilized zirconia ceramic heater is used to reduce the emissions from the engine and improve engine output behavior. The relevant parameters such as brake thermal efficiency, brake specific fuel consumption (BSFC) and emissions are calculated for ethanol-diesel blends with 5% of additive 15/85, 25/75, 30/70 and 35/65 by volume. The emulsifier replaced a corresponding part of the diesel. Thus, the 15/85 blend ratio corresponds to 85% diesel fuel, 5% additive and 10% ethanol, and similarly for the other blends. The stabilized zirconia ceramic heater is used to reduce the emissions by 38% of NOx, under half load conditions for the blends of B5D85E10 (15/85) (5% additive 85% diesel, 10% ethanol) gives minimum CO emissions, unburned HC emissions by 7.5 ppm for B0D100E0 (0/100) (pure diesel) and improve engine output behavior to 1.8%. Compression tests were carried out for 1500 rpm of B5D85E10 blends for compression ratios of 13.2, 13.9, 14.8, 15.7, 16.9, 18.1 and 20.2, upto 3 kw power. The performance and emission characteristics at compression ratio (cr) of 14.8 are improved. The compression ratios lesser than 14.8 and greater than 14.8 showed a drop in break thermal efficiency, rise in fuel consumption along with increased smoke densities.

Keywords: ethanol, amyl nitrate, emissions, ceramic heater, aluminium oxide, compression ratio.

I. INTRODUCTION

Innovative thinking led to find various techniques by which alcohol can be used as fuel in diesel engines. Amongst the fuel alternatives proposed, the most favored one is ethanol. So far, no established method is available to run a normal diesel engine with a compression ratio from 13.2 to 20:2 by using ethyl alcohol as fuel. This is because; the properties of alcoholic fuels differ from the properties of diesel fuel. The specific tendency of alcohols, to ignite easily from a hot surface makes it suitable to ignite in a diesel engine by different methods. The advantage of this property of alcohol enables us to design and construct a new type of engine called the surface ignition engine. Ethanol 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 [1]. When considering an alternative fuel for use in diesel engines, a number of issues are important. These issues include supply and distribution, integrity of the fuel being delivered to the engine, emissions and engine durability. The purpose of this review is to discuss the engine performance of four stroke ceramic heater C.I. engine using ethanol-diesel blends [4].

The two most commonly known methods of combustion in an I.C engines are the compression ignition and spark ignition. In the C.I engines, the working medium, air is compressed to a high pressure and temperature. Then fuel is injected into the combustion chamber where the jet disintegrates into a core of fuel surrounded by an envelope of air and fuel particles created by the automation and vaporization of the fuel and the turbulence inside the combustion chamber. During the delay period, the fuel is atomized, vaporized and mixed with air. Its temperature increase leads to chemical reaction which accelerates until inflammation [8].

A ceramic heater [3] surface ignition C.I engine aluminium oxide coating on piston head is able to operate at higher temperature enabling combustion of fuel at complete resulting to increase combustion efficiency. This should increase performance, decrease fuel consumption and reduce pollution [6]. 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, and due to its inherent self-regulating characteristics. Ceramic heater for diesel combustion would represent a simple low cost and easy approach in improving diesel engine performance [5]. Compatibility and bonding to produce a homogeneous blends. The blends formed spontaneously and required only minor stirring. The ethanol-diesel blends transparently indicating that the dispersion sizes are less than a quarter of a wavelength of light [7].

In ceramic heater C.I engine an injection pressure and rate of injection can also offset the adverse effect of ceramic heater. In this new system, decreased in pre mixed of combustion due to decrease in ignition delay and increase the Brake Specific Fuel Consumption (BSFC). Partially Stabilized Zirconia (PSZ) Ceramic Heater is fitted inside the cylinder, because of its very high fracture toughness among ceramics, it has one of the highest maximum service temperatures (2000°C) among all of the ceramic and it retain some of its mechanical strength close to its melting point (2750°C). PSZ ceramic heater is used in diesel engine because of two very notable properties, one is high temperature capability and other is low thermal conductivity. None of the other ceramics possess a thermal conductivity as low as the zirconias. This means that engine make out of zirconia would retain much of the heat generated in the combustion chamber instead of loosing it to the surroundings [9]. Amyl nitrate (B) [12] additive is used to satisfy mixture homogeneity and prevent phase separation. The mixing protocol considered of first blending the emulsifier into the ethanol and then blending this mixture into the diesel fuel [10].

The relevant parameters such as brake thermal efficiency, brake specific fuel consumption (BSFC) and emissions are calculated for ethanol-diesel blends of 15/85, 25/75, 30/7 and 35/65 [10] by volume (B5D85E10, B5D75E20, B5D70E25 and B5D65E30) [2]. The emulsifier replaced a corresponding part of the diesel. Thus, the 35/65 blend ratio corresponds to 65% diesel fuel, 5% additive and 30% ethanol, and similarly for the other blends [10]. In diesel vehicle, Particulate Matters (PM) and NOx are exhausted and the PM is designated as one of major cancer materials and the regulation on exhaust gases is getting stringent [15]. The Diesel Particulate Filter trap (DPF) is very active in several advanced countries because it is a very unique technique reducing PM. DPF can be classified as filtration and regeneration technique, but it is very difficult situation in commercializing due to durability of filter and high costs [13,14]. This technique can eliminate most of PM in filter trap and in future the application of DPF is very promising as an after-treatment technique. This study is given the performance of ceramic heater and fuel additive type surface ignition blended fuel C.I engine [16]. DPF the size of most of particulate matter is less than 1 mm in radius, it is easy to penetrate into sinus or any other organs and stay for a long time and causes lung cancer. Therefore, DPF is called an overall system collecting carbon from emission of diesel engine and decrease exhaust gases. DPF is a superior system in reduction of PM because it contributes to reduce 70% PM. Meanwhile, manufacturing cost is too high and the durability is low and gives problems in production. Also, as filter trap collects PM, the engine performance and fuel consumption is getting worse due to occurred back-pressure. The fundamental system of DPF constitutes filter trap, regeneration and control units [17, 18].

II EXPERIMENTAL WORK

A different speeds of stationary four stroke ceramic heater[9] surface ignition [8] C.I engine is selected for the experiment. The major specifications of the engine are given in Table. 1 and properties of fuels used are given in Table. 2. The engine is connected with dynamometer, air stabilizing tank, diesel and ethanol blends consumption measuring device, exhaust gas analyzer etc. A ceramic heater is fixed in side of the cylinder and connected by 12 volt D.C battery to heating combustion chamber. Diesel fuel and ethanol-diesel blends with additives by 0/100, 15/85, 25/75, 30/70 and 35/65 (B0D100E0, B5D85E10, B5D75E20, B5D70E25 and B5D65E30) are tested. The ethanol and additive are obtained from the local market. The engine is run on no-load condition and its speeds are adjusted to 1250 rpm and 1500 rpm by adjusting the screw provided with the fuel injector pump. The engine is run to gain uniform speed after which it is gradually loaded. The experiments are conducted at six power levels. For each load condition, the engine is run for at least 10 minutes after which data is collected. The experiment is repeated four times and the average value is taken. The observations made during the test for the determination of various engine parameters BSFC, Brake thermal efficiency and exhaust emissions [7]. The set up is connected with Data Acquisition System.

A dynamometer is used for measuring the power of engine output. Exhaust gas analyzer is used for measuring the emissions of CO, HC and NOx from the engine. A fuel consumption meter is used for measuring the brake specific fuel consumption of the engine. Figure. 1 shows the ceramic heater assemble of the engine. Figure. 2 shows the experimental set up of the work.

Fig. 1. Ceramic Heater Assembly

Table 1. Tested Engine Specifications

Engine type	4-S single cylinder aluminium oxide coating on piston head
Make	10.0 KW
Power	102 × 110
Bore'stroke (mm) Displacement	898 CC
Volume	Water cooled
Cooling system	Force feed
Lubrication system Attachment	Ceramic heater (12 Volt, D.C)

Table 2. Properties of blending stocks

Properties	Diesel	Ethanol	Amyl.
Boiling point °C	180	78	99
Flash Point °C	65	10	47
Density,g/ml at 20°C	0.829	0.789	0.872
Oxygenate (Wt %)	0.84	35	47
Carbonate (Wt%)	–	52	21
Hydrogen (Wt %)	87	13	1.2
Viscosity,CS at 40°C	13	1.2	1.9
Cetane number	180	48	6

III RESULTS AND DISCUSSIONS

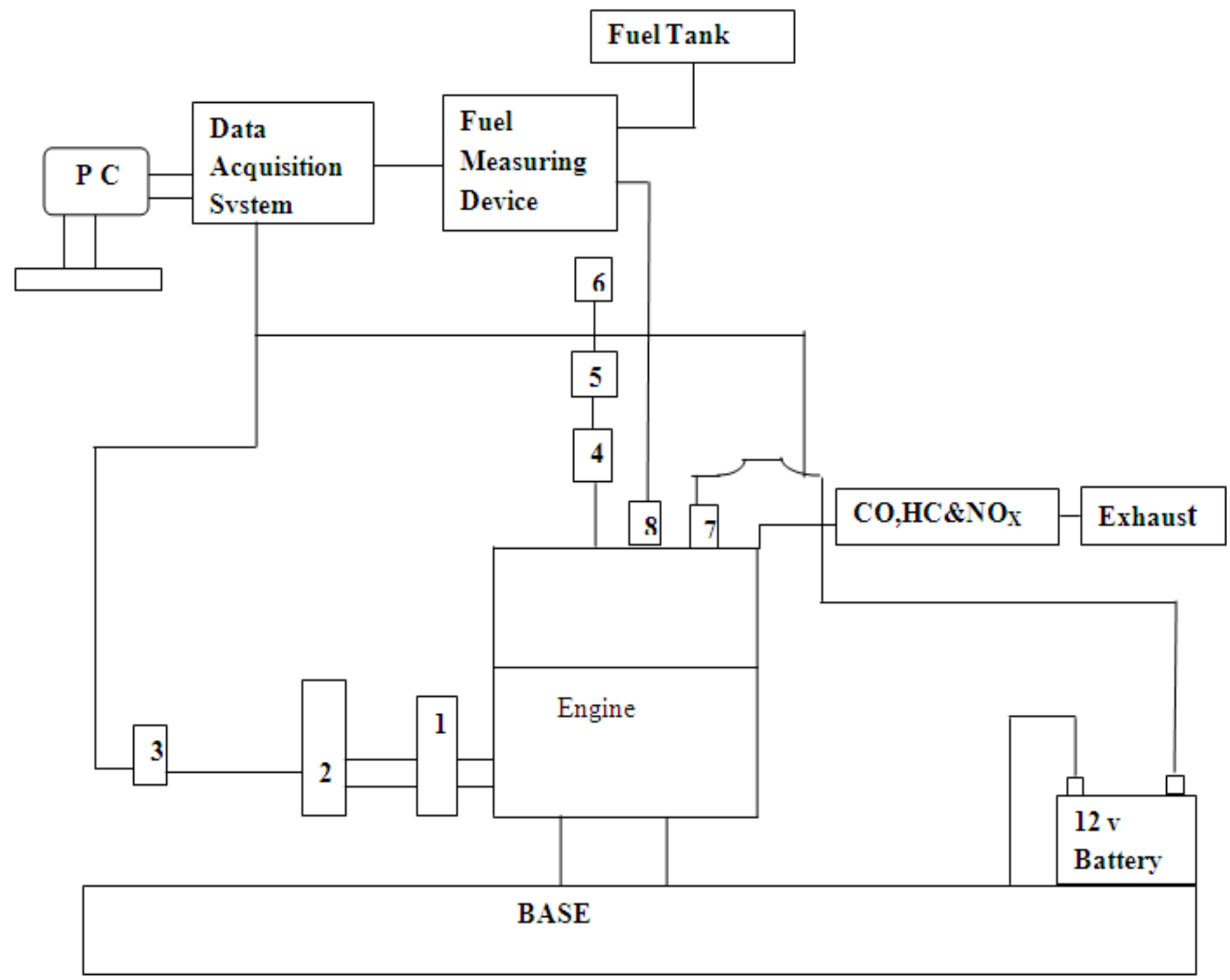
The experimental tests are carried out on the ceramic heater diesel engine using diesel and the blended fuels with amyl nitrate additive on different speeds. The relevant parameters such as engine brake specific fuel consumption, brake thermal efficiency and emissions are calculated for the speeds of 1250 rpm and 1500 rpm. The engine emissions of CO, unburned HC and NOx are analyzed using the exhaust gas analyzer. The additive which has favourable effects on the physic-chemical properties associated with injection, ignition and combustion of fuel mixtures containing 10%, 20%, 25% and 30% of ethanol [11]. The results are shown as follows.

A. Engine performance for amyl nitrate additive at different speeds

The ratio of ethanol- diesel blends gives various fuel consumption according to the percentage of ethanol present in the diesel fuel. If more ethanol is added with diesel, gives more fuel consumption.

Figure. 3 shows that the engine runs at 1250 rpm on different engine loads, for the blends of B5D65E30 (35/65), the BSFC is increased to 62 g/Kwhr and for the blends of B5D75E20 (25/75) BSFC is increased to 58 g/Kwhr.The results shows that trend of the increase of fuel consumption with the increase percentage of ethanol in the blends.

Figure. 4 shows that the engine runs at 1500 rpm, for the blends of B5D75E20 (25/75), the BSFC are increased at maximum engine load and 60 g/Kwhr for B5D70E25 (30/70) These increase of fuel consumption is due to the lower heating value of ethanol than that of pure diesel.



1. Flywheel
2. Dynamometer
3. R.P.M. Measuring device
4. Air stabilizing tank
5. Digital air flow meter
6. Air filter
7. Ceramic heater
8. Injector.

Fig. 2. Experimental Setup

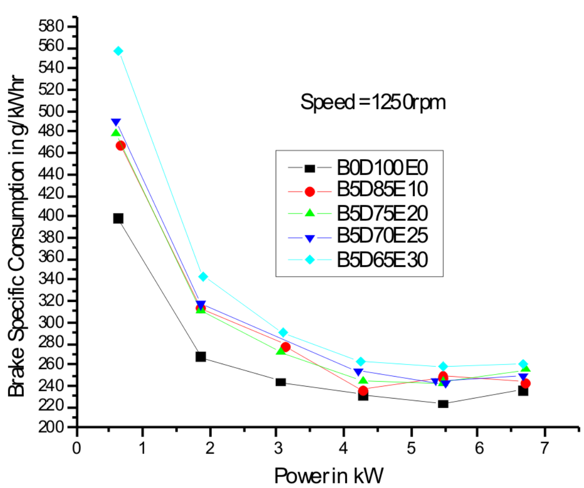


Fig. 3. Brake Specific fuel Consumption of the engine for 1250 rpm

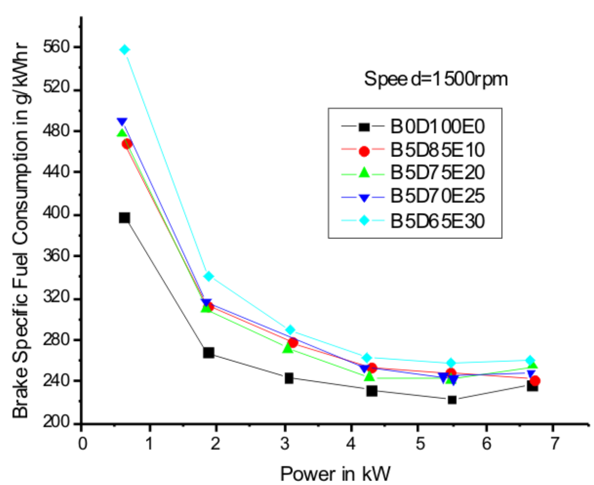


Fig. 4. Brake Specific fuel Consumption of the engine for 1500 rpm

The differences in brake specific fuel consumption is a reflection of the differences in fuel density and calorific values. Since the blends have less density and lower calorific values, it resulted in their higher fuel consumption and as such higher brake specific fuel consumption.When compared with alternate fuel, brake specific fuel consumption in case of ethanol is much less.

B. Results of the Brake thermal efficiency

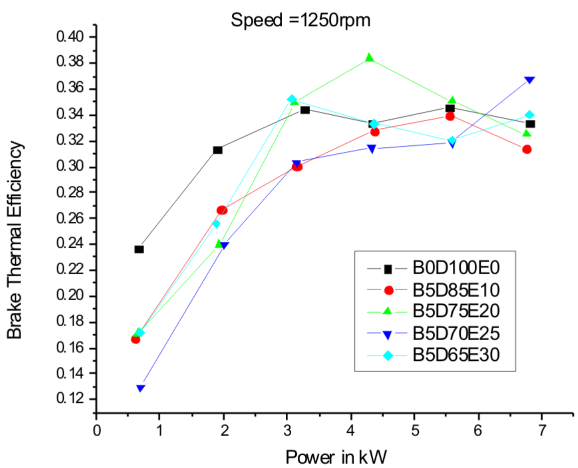


Fig. 5. Brake Thermal Efficiency of the engine for 1250 rpm

Figure. 5 shows that the results of the break thermal efficiency of the engine. When the engine runs at the speed of 1250 rpm, for the blend of B5D75E20 (25/75) by 1.8%, the thermal efficiency is increased and upto half load thermal efficiency is increased for the blends of B5D65E30 (35/65) by 2.3%

Figure. 6 shows that when the engine runs at the speed of 1500 rpm, the break thermal efficiency is increased for the blends of B5D75E20 (25/75) by 5% at high power and B5D70E25 (30/70) by 2.4% at low power.

The brake thermal efficiency for the same load condition decreased with increasing ethanol content in the blend. This is due to the higher fuel consumption of blended fuel than the diesel alone and lower calorific values of ethanol-diesel blends as compared to diesel alone.

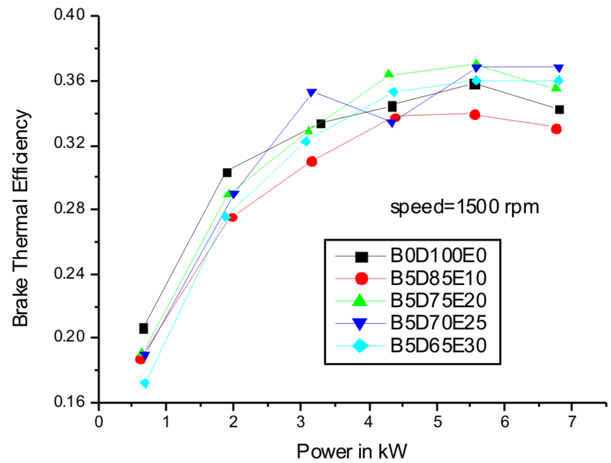


Fig. 6. Brake Thermal Efficiency of the engine for 1500 rpm

C. Exhaust emissions

The exhaust emissions are measured in terms of CO, Unburned HC and Oxides of Nitrogen (NOx) emission. The results for diesel fuel as well as ethanol-diesel blends are given below. The oxygen content of the blended fuels would help to increase the oxygen-to-fuel ratio in the fuel-rich regions. The resulting more complete combustion leads to reduce CO in the exhaust. The percentage of ethanol in the blends are increased, NOx emission is reduced. This is because of the air-fuel ratio in the case of ethanol-diesel blends is lower as compared to diesel alone. Also, the latent heat of vaporization of ethanol lowers at same temperature resulting in lower NOx emission.

D. Carbon monoxide (CO) emission

Figure. 7 shows that the CO emission from the engine fuelled by the blends are higher than those fuelled by pure diesel. The higher percentages of the ethanol give more CO emission. For higher engine loads which are above half of the engine load, the CO emission becomes lower than that fuelled by diesel for all the blends for the speed of 1250 rpm.

This is due to the ethanol contains oxygen element. When the engine above its half load, the temperature in the cylinder is high, which makes the chemical reaction of fuel with oxygen be easier and the combustion becomes more complete by the help of ceramic heater.

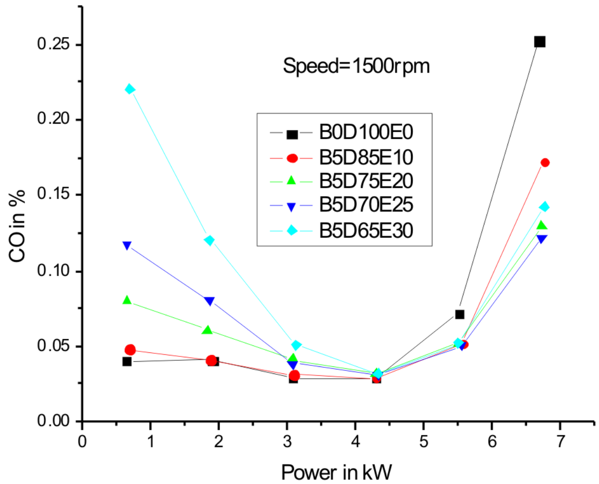


Fig. 7. CO Emission for 1250 rpm

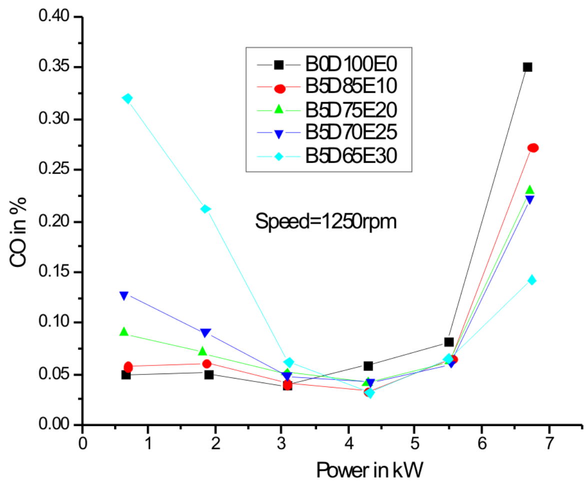


Fig. 8. CO Emission for 1500 rpm

Figure. 8 shows that the reductions of CO emission at full load is due to the more complete combustion. The phenomenon or trend is due to that ethanol contains oxygen element in it. When the engine above its half load, the temperature in the cylinder is high, which made the chemical reaction of fuel with oxygen be easier and the combustion is fully completed in 1500 rpm. CO emission is same for all blends at half load and 4.8% CO emission is increased at low and high load for B5D70E25 (30/70) at the speed of 1500 rpm.

E. Unburned hydro carbon (HC) emission

The level of unburned hydro carbons (HC) in exhaust gases is generally specified in terms of the total hydro carbon concentration expressed in parts per million carbon atoms.

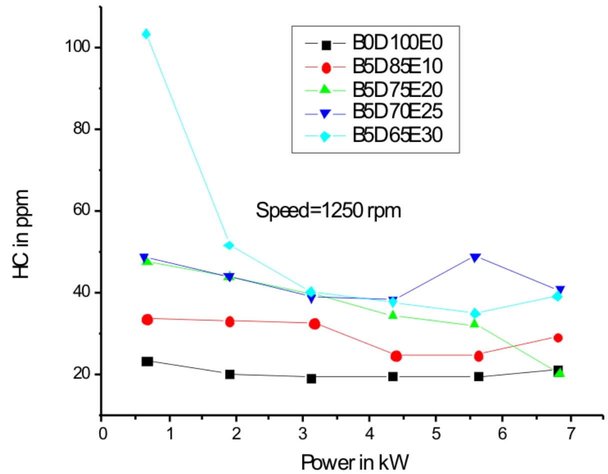


Fig. 9. HC emission for 1250 rpm

Figure. 9 shows that the engine runs at 1250 rpm, the graph shows that, for the blends of B5D85E10 (15/85) the HC is reduced. This is due to the high temperature in the ceramic heater engine cylinder to make the fuel be easier to react with oxygen when the engine runs on the top load and high speed.

The figure. 10 shows that the results of unburned HC emission from the engine for the blend fuels are all higher when the engine run at the speed of 1500 rpm. The HC emission became less as the loads increased. Less emission for B0D100E0 (0/100) and B5D85E10 (15/85) by 25 ppm and 12 ppm respectively.

This is due to the high temperature in the engine cylinder to make the fuel be easier to react with oxygen when the engine runs on the top load and 2000 rpm.

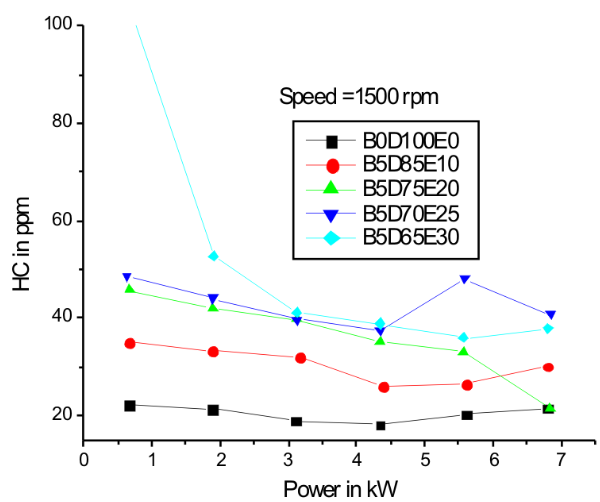


Fig. 10. HC Emission for 1500 rpm

F. Nitrogen oxides (NOx) emission

Figure 11 shows that the engine runs at the speed of 1250 rpm and above half of the engine load. The NOx emission from the enigne were higher than those of diesel. NOx emission is reduced for the blends of B5D70E25 (30/70) due to the fuel air mixture, with a spread in composition about stoichiometric burns. During the mixing controlled combustion phase the burning mixture likely to be closer to stoichiometric by the help of ceramic heater.NOx emission is reduced for the blends of B0D100E0 (0/100) and B5D70E25 (30/70) by 100 ppm at the speed of 1250 rpm.

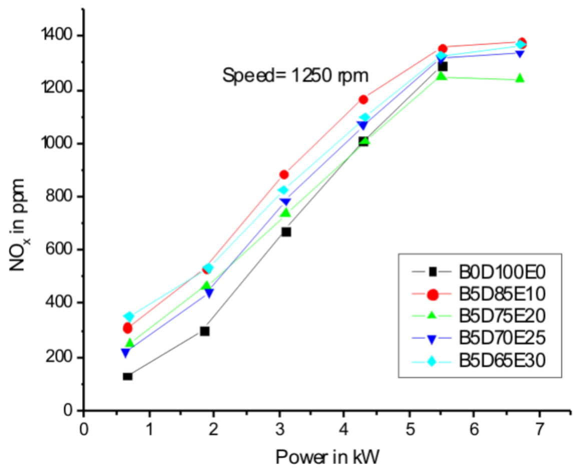


Fig. 11. NOx emission for 1250 rpm

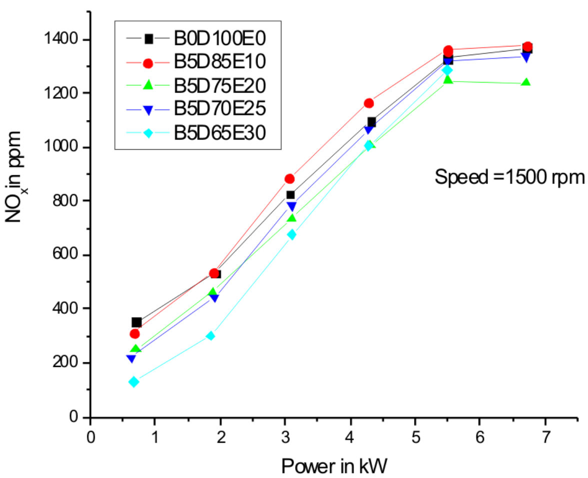


Fig. 12. NOx emission for 1500 rpm

The figure. 12 shows that the results of NOx emissions.When the engine runs at 1500 rpm the NOx is reduced for the blends of B5D65E30 (35/65) upto half load of the engine by 225 ppm.

From the investigation the NOx emission from the engine is reduced at the low speed for blended fuels. At high speed NOx emission is not stable condition. This is due to most relevant source from engine combustion.

G. Compression test

Compression tests were carried out for 1500 rpm of B5D85E10 blends for compression ratios of 13.2, 13.9, 14.8, 15.7, 16.9, 18.1 and 20.2, upto 3 kw power. Results showed significant improved performance and emission characteristics at a compression ratio of 14.8. The compression ratios lesser than 14.8 and greater than 14.8 showed a drop in break thermal efficiency, rise in fuel consumption along with increased smoke densities.

(i) Brake thermal efficiency

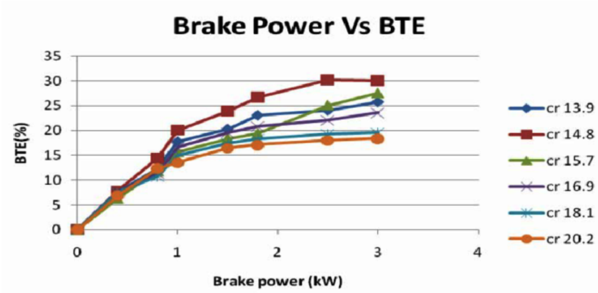


Fig. 13. Brake power Vs Brake thermal efficiency

Figure. 13 shows that the maximum brake thermal efficiency is obtained at a compression ratio of 14.8. The least brake thermal efficiency is obtained at a compression ratio 20.2. Hence with respect to brake thermal efficiency, 14.8 can be treated as optimum. This can be attributed to the better combustion and better intermixing of the fuel and air at this compression ratio (cr).

(ii) Fuel consumption

The better fuel consumption was obtained at a compression ratio of 14.8 (Figure 14). The higher and lower compression ratios than 14.8 resulted in high fuel consumptions. The fuel consumption at a compression ratio of 18.1 and 20.2 was almost the same. The high fuel Consumption at higher compression ratios can be attributed to the effect of charge dilution. At the lower sides of the compression ratios, the fuel consumption is high due to incomplete combustion of the fuel.

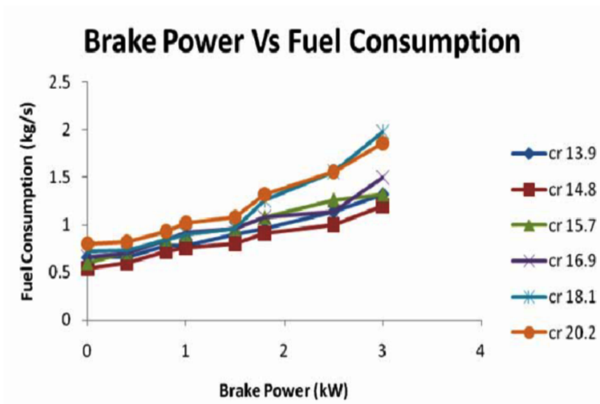


Fig. 14. Brake power Vs Fuel consumption

(iii) Exhaust gas temperatures

Exhaust gas temperatures were found to be increasing with the increase in load and the compression ratio (Figure. 15). The highest exhaust gas temperature was recorded for the compression ratio 20.2 while the least was for 13.2.

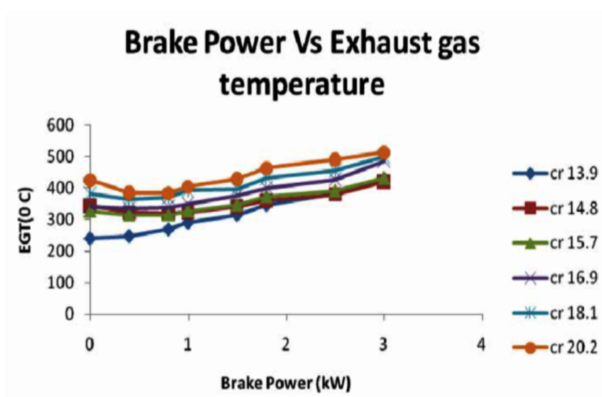


Fig. 15. Brake power Vs Exhaust gas temperature

(iv) Smoke density

Smoke density is measured with the help of Hat ridge smoke meter which measures the smoke density in Hat ridge smoke units (HSU). Figure. 16 shows that the smoke density was less for the compression ratio 14.8 which is the optimum compression ratio for the C.I engine with diesel.

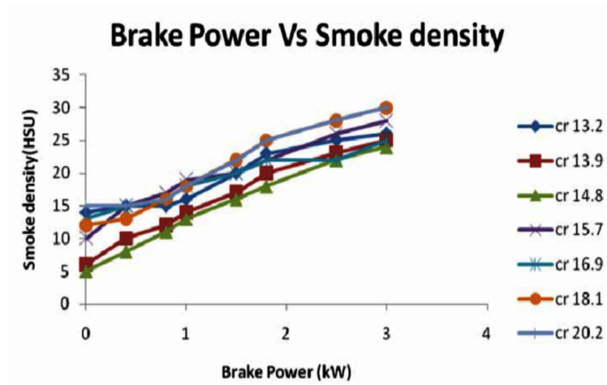


Fig. 16. Brake power Vs Smoke density

IV CONCLUSIONS

An experimental investigation was conducted on the blends of ethanol - diesel fuel using four stroke ceramic heater surface ignition aluminium oxide coated piston head C.I engine. The tested blends were from 15/85, 25/75, 30/70 and 35/65 of ethanol by volume and also with 5% of the additive of amyl nitrate. The engine was operated with each blends at different powers on which the engine speeds of 1250 rpm and 1500 rpm. The Experiment showed that the amyl nitrate is a good additive for mixing diesel with ethanol blends. Using ceramic heater improves the engine performance and control the emissions from the engine. The brake specific fuel consumption is slightly increased for 25/75 and 30/70 of ethanol by volume. The brake specific fuel consumption is slightly increased by 62 g/Kwhr for B5D65E30 (35/65) and 58 g/Kwhr for B5D70E25 (30/70) blends at 1250 rpm and 60g/Kwhr for B5D65E30 (35/65)at 1500 rpm. The brake thermal efficiency is increased for the blends of B5D75E20 (25/75) by 1.8% and B5D65E30 (35/65) by 2.3% at the speed of 1250 rpm. When the engine runs at 1500 rpm the brake thermal efficiency is increased for the blends of B5D75E20 (25/75) by 5% at high power and B5D70E25 (30/70) by 2.4% at low power. The higher percentages of the ethanol give more CO emission by 70% maximum. At half load CO emission is average. For higher engine loads which are above half of the engine load, the CO emission became lower than that fuelled by pure diesel for all the blends for the speed of 1250 rpm. CO emission is same for all blends at half load and 4.8% CO emission is increased at low and high load at the speed of 1500 rpm. The blends of B5D85E10 (15/85) the HC emission is reduced by 20 ppm. When the engine runs at the speed of 1500 rpm. The HC emission became less as the loads increased. Less emission for B0D100E0 (0/100) and B5D85E10 (15/85) by 25 ppm and 12 ppm respectively for the speed of 1250 rpm. NOx emission is reduced for the blends of B0D100E0 (0/100) and B5D70E25 (30/70) by 100ppm at the speed of 1250rpm. When the engine runs at 1500 rpm the NOx is reduced for the blends of B5D65E30 (35/65) up to half load of the engine by 225 ppm. Results showed significant improved performance and emission characteristics at a compression ratio of 14.8. The compression ratios lesser than 14.8 and greater than 14.8 showed a drop in break thermal efficiency, rise in fuel consumption along with increased smoke densities.

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