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EFFECTS OF YTTRIA STABILISED ZIRCONIA COATING ON PERFORMANCE AND EMISSION CHARACTERISTICS OF BIO-DIESEL (CITRONELLA OIL) FUELLED C.I ENGINE

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Abstract:**Diesel based fuels play a vital role in rapid depletion of conventional energy sources along with increasing demand and also major contributors of air pollutants. Major portion of today's energy demand in India is being met with fossil fuels. Hence it is high time that alternate fuels for engines should be derived from indigenous sources. As India is an agricultural country, there is a wide scope for the production of oils from different oil seeds. Ceramic coatings in diesel engines lead to advantages including higher power density, fuel efficiency, and high combustion chamber temperature. Using thermal barrier coating can increase engine power and decrease the specific fuel consumption and increase the exhaust gas temperature. Although several systems have been used as TBC for different purposes, yttria stabilized zirconia has received the most attention. Several important factors playing important roles in thermal barrier coating lifetimes including thermal conductivity, chemical stability at the service temperature, high thermo mechanical stability to the maximum service temperature and the thermal expansion coefficient. Hence an attempt is made to analyze the performance and emission characteristics of diesel and different blends of citronella oil using yttria stabilized zirconia coated piston on a four stroke single cylinder water cooled Diesel Engine test rig in I.C Engines Laboratory. Experiments were carried out on a diesel engine using different blends of citronella oil namely B10, B20, B30, and B40 on volume basis. Performance parameters such as brake power, specific fuel consumption, and thermal efficiencies are calculated based on experimental analysis of the engine. Emissions such as carbon monoxide, carbon dioxide, NO_X and unburned hydrocarbon are measured.**

Keywords**: Citronella Oil, Yttria stabilized zirconia, single cylinder 4-stroke diesel engine, Engine performance.**

I.INTRODUCTION

Diesel engines are the major source of transportation, power generation, marine applications etc. Hence diesel is being used extensively, but due to gradual depletion of world petroleum reserves and the impact of environmental pollution of increasing exhaust emissions, there is an urgent need for suitable alternative fuels for use in diesel engines. In view of this, various oils like flaxseed oil, jatropa, palm oil, sunflower oil etc., are considered as alternate fuels to diesel which are promising alternatives because they have the advantages – they are renewable, eco-friendly and produced easily in rural areas, where there is an acute need for modern forms of energy. If these fuels serve the purpose of diesel to some extent they will be useful to the rural areas in providing employment as well as agriculture energy needs. If these fuels serve the purpose to a larger extent they will be good substitutes in industrial, transportation etc.

Bio-diesel can be made using vegetable oil. It is a clean burning fuel, which means that it does not give off harmful emissions that cause environmental effects. Since bio-diesel is oxygenated, diesel engines have more complete combustion with bio-diesel than with petroleum. Bio-diesel is safer to use than petroleum diesel. The use of bio-diesel in a conventional diesel engine results substantial reduction of un-burnt hydrocarbons, carbon monoxide, and particulate matter.

Ceramic coatings applied to diesel engine combustion chambers are aimed to reduce heat which passes from in-cylinder to engine cooling system. Engine cooling systems are planned to be removed from internal combustion engines by the development of advanced technology ceramics. One can expect that engine power can be increased and engine weight and cost can be decreased by removing cooling system elements (coolant pump, ventilator, water jackets and radiators etc.).

More silent engine operation can beobtained considering less detonation and noise causing from uncontrolled combustion. Another important topic from the view point of internal combustion engines is exhaust emissions. Increased combustion chamber temperature of ceramic coated internal combustion engines causes a decrease in soot and carbon monoxide emissions

II.LITERATURE SURVEY

Zafer Utlu et.al [1] investigated waste frying oil on direct injection diesel engine found that emission values are decreased by17.4% for CO and 1.45% for NOx; the smoke intensity is increased by 22.46%. The exhaust temperature of Waste frying oil methyl ester is decreased by 6.5%. M.Pugazhvadivu et.al [2] used preheated waste frying oil as fuel in DI diesel engine. The high viscosity of fuel was reduced by preheating by 135°C and showed by increasing in BSEC & BTE and reduction in CO & Smoke. A.S. Ramadhas et.al [3] tested the rubber seed oil and reported that more carbon deposits due to incomplete

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combustion. Jatropha oil in preheated and blends were used by Deepak Agarwal et.al [2007] and the results showed that BSFC and exhaust gas temperature for unheated Jatropha oil was found to be higher compared to diesel and heated Jatropha oil and also thermal efficiency was lower for unheated Jatropha oil compared to heated Jatropha oil and diesel. CO2, CO, HC and smoke opacity were higher for Jatropha oil compared to that of diesel. J.R. Kumar, C.J. Vikram and P. Naveenchandran et.al [4] investigated to evaluate the performance and Emission characteristics of Kirloskar Diesel in the internal combustion engine by using different blends of Citronella Oil based biodiesel under different Operation Conditions. The primitive objective is to determine the optimum performance of this citronella biodiesel. Latest studies are going on to improve the emission characteristics and also to increase the efficiency of a diesel engine by using thermal barrier coatings on the piston. Thermal barrier coatings have been apply to the internal combustion engine in particular the combustion chamber and cylinder lands to act as a low heat rejection engine, heat engine is improvement of their thermal efficiency. Naveen. P, C.R. Rajashekhar, C. Umashankar& Vinayaka Rajashekhar Kiragi [5] Tested the engine with diesel and at different proportionality of diesel with Honge bio-diesel and by varying torque without coating. Then, the piston head was coated with thermal barrier material. The layer of thermal coating was made of Alumina-Titanium oxide (Al2O3/TiO2) plasma coated on to the base of NiCrAl. Then the coated piston was tested at the same operation conditions as the standard (without coating) engine. The results indicate a reduction in specific fuel consumption and an improved brake thermal efficiency for titanium oxide coated piston.Imdat Taymaz [6] used thermally insulated material such as CaZrO3 and MgZrO3 for insulation of different surfaces of combustion chamber. An improvement of efficiency of 2-5% was observed.B.M.Gnanasekaran, T.Senthilkumar [7], used Zirconia coating on the piston, cylinder head and valves on the performance of the modified four stroke petrol engine and emission characteristics of the exhaust gas. As the zirconia is a low thermal conductivity material, it reduces the heat loss from the cylinder to the surroundings. Therefore the efficiencies are increased and the emissions are reduced because of various chemical reactions takes place inside the cylinder at high temperature. Brake thermal efficiency and mechanical efficiency of coated piston are increased by the average value of 9% and 25% respectively.7% reduction in total fuel consumption and 6% reduction in specific fuel consumption were achieved with the coated piston. 14% of NOX emissions were reduced due to coating because of nitrogen has observed by zirconia. 23% of unburned HC emissions were reduced by using the coated piston. CO emissions are reduced by 48% because of at high temperature C easily combines with O2 and reduces CO emission.

III.METHODOLOGY

Citronella grass (*Cymbopogonnardus*) is a nativearomatic tally sedge (family: Poaceae) which grows in many parts of tropical and sub-tropical South East Asia and Africa. In India, it is cultivated along Western Ghats (Maharashtra, Kerala), Karnataka and Tamil Nadu states besides foot-hills of Arunachal Pradesh and Sikkim. Lemongrass is native to India and tropical Asia. Citronella grass (*Cymbopogonnardus*and*Cymbopogonwinterianus*) grows to about 2 meters (about 6.5 feet) and has red base stems. These species are used for the production of citronella oil, which is used in soaps, as an insect repellent in insect sprays and candles. The citronella essential oil is extracted from Cymbopogon citrates. The important chemical components of citronella oil are myrcene, citronellal, geranyl acetate, nerol, geraniol, neral and traces of limonene and citral.

Fig 1: Citronella plant

*A.Extraction of oil:*The oil is extracted from the grass through steam distillation process. The grass is chopped into shorter lengths and placed in to the still. The steam is allowed to pass into the still with some pressure from the boiler. The mixture of vapours of water and citronella oil passes into the condenser. As the distillation proceeds, the distillate collects in the separator. The oil being lighter than water and insoluble floats on the top of the separator and is continuously drawn off. The oil is then decanted and filtered. The collected oil is stored in containers, preferably of glass or well-tinned iron. Containers should completely be filled to exclude any air and protect from sunlight as they affect the oil content.

*B. Trans esterification:*Trans esterification is the widely used process. The oil extracted along with any suitable alcohol from the seeds in presence of a catalyst is subjected to this reaction. The products formed will be alkyl esters and glycerol. The alkyl esters so formed is referred to as biodiesel. In general, the catalysts used for Trans esterification process can be bases, acids or immobilized enzymes. For the Trans esterification to give a high yield, the alcohol should be free of moisture and the free fatty acid content must be <0.5%. Trans esterification is a reversible reaction but in the production of biodiesel, the backward reaction doesn't take place or is negligible because the glycerol formed is immiscible with the product leading to a two phase system. Glycerol is removed from alkyl esters after the reaction has been carried out. The low solubility of glycerol in the esters makes its separation occur quickly and can be

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accomplished by settling or centrifugation processes .To enhance the separation of glycerol, water is added to the reaction mixture after the transesterification process is complete. Once glycerol has been separated, the alkyl esters will enter a neutralization step and then excess alcohols will be removed and then water washing is done. Acids will be added to the biodiesel product for neutralizing the residual catalyst and to split out any soap that would have been formed during the reaction process. The soaps formed will react with acids and form water soluble salts and free fatty acids. Water washing process will remove the soluble salts and the free fatty acids will stay in the biodiesel. Neutralization step prior to washing decreases the amount of water needed and reduces the potential for emulsions to form when the wash water is added to the biodiesel. Trans esterification process depends on water content of fats or oils, temperature of the reaction, catalyst, reaction time as well as on the fatty acid content.

C.Plasma spray coating process:

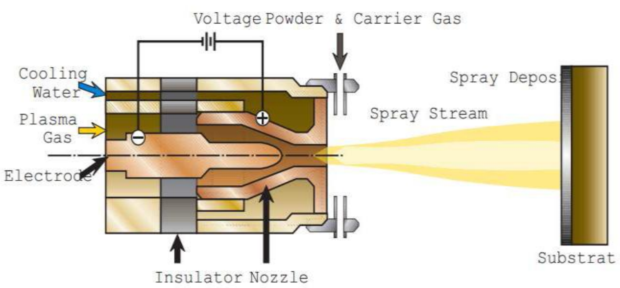

Fig 2. Schematic diagram of plasma spry technique

Procedure:

An electric arc is formed between a cathode andthe concentric nozzle of the spray gun. A mixture of gases with a high flow rate along the electrode is ionised by the arc, and forms plasma. This plasma stream is pushed out of the nozzle, where the powder of the Yttria stabilised zirconia coating material is injectedinto the plasma jet. The heat and velocity of the plasma jet rapidly melts and accelerates the particles so that they are propelled to form a coating of thickness 0.2mm on to the substrate.

Fig 3. Uncoated baseline engine piston (left) and YSZ coated piston (right).

IV.EXPERIMENTAL WORK

In order to analyze the performance and emission characteristics of internal combustion engine, an experimental set-up was developed. In the present work, Yttria stabilized zirconia (YSZ) was coated on piston crown and citronella oil was used as biodiesel on volume basis. The experiment was carried out on a single cylinder water cooled direct injection diesel engine. Eddy current dynamometer is used for loading i.e. electrical loading. The engine Specifications are given in Table-1.

TABLE I
TEST ENGINE SPECIFICATIONS

Particulates	Specifications
Model	AVI
Make	Kirloskar Oil Engine Ltd.
Arrangement of cylinders	Vertical
No of cylinders	1
Lubricant	SAE 20/SAE40
Bore	85mm
Stroke length	110mm
Rated speed	1500 rpm
Rated power	5HP
Starting	Hand start with crank handling
Type of cooling	Water cooled

IV. RESULTS AND DISSCUSSIONS

The performance of the engine was evaluated in terms of brake specific fuel consumption, brake thermal efficiency and mechanical efficiency. The emission characteristics of the engine were studied in terms of concentration ofCO, HC and NO_X the results obtained for citronella oil blends with YSZ coated piston is compared with the results of pure diesel.

1. Brake specific fuel consumption:

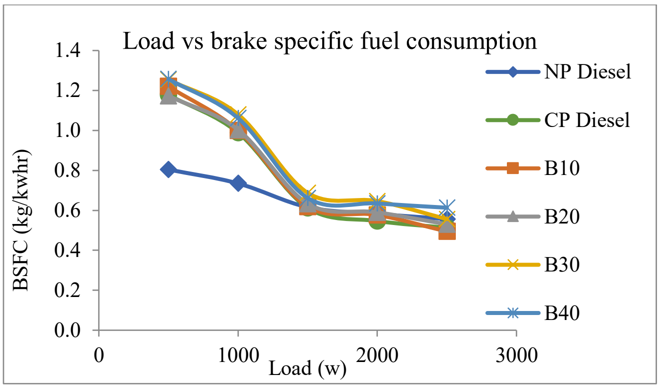

Fig 4: load vs. Brake specific fuel consumption

The result for the variations in the brake specific fuel consumption (BSFC) with load is presented in the fig 4. The variation of Brake specific fuel consumption with load for

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Diesel, B10, B20, B30 and B40. We can observe from the above graphs that the B.S.F.C for coated piston for the coated piston and the blends B10 and B20 when compared to normal piston. This is due to proper combustion of the fuel takes place due to high temperature in combustion chamber because of thermal resistant due to the coated material and also due to composition of yttria stabilized zirconia which acts as catalyst to enhance combustion and thus reduces the fuel consumption for yttria stabilized zirconia coated piston. The BSFC of B10, B20 blends are low particularly at load 2500W compared to the other fuels. The BSFC is reduced to 0.07Kg/KW-hrfor blend B10 of citronella oil in Yttria stabilized zirconia coated engine compared to conventional engine.Therefore it appears that the thermal barrier coatings have considerable influence at reduction in Brake specific fuel consumption. It is mainly due to the higher temperature reached in the combustion chamber.

2.Mechanical efficiency:

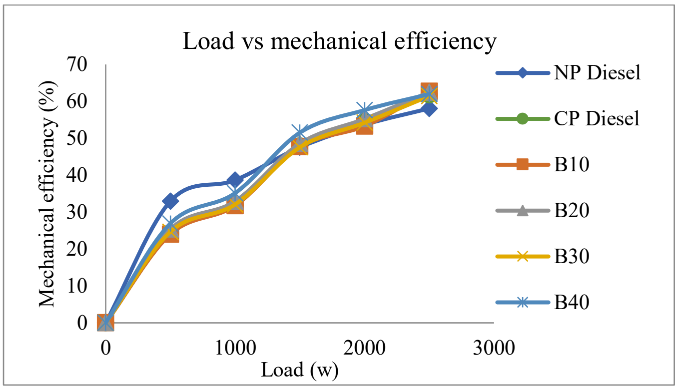

Fig5: Variation of mechanical efficiency with load

From Fig.5, the variation of mechanical efficiency with respect to load can be observed. At higher loads the Mechanical efficiency of the engine by using YSZ coated piston for diesel, B10, B20, B30, B40 are observed as 61.8%, 62.75%, 62.45%, 61.44% and 61.97% respectively. From the graph it can see that the mechanical efficiency for coated piston for all fuels is more when compared to the normal piston with diesel (58.08%). Particularly the B10 fuel gives more mechanical efficiency than the other fuels. From the above results it shows that due to the high temperature in the combustion chamber due to the thermal resistance of the coated piston where heat loss is minimal.

3.Brake thermal efficiency:

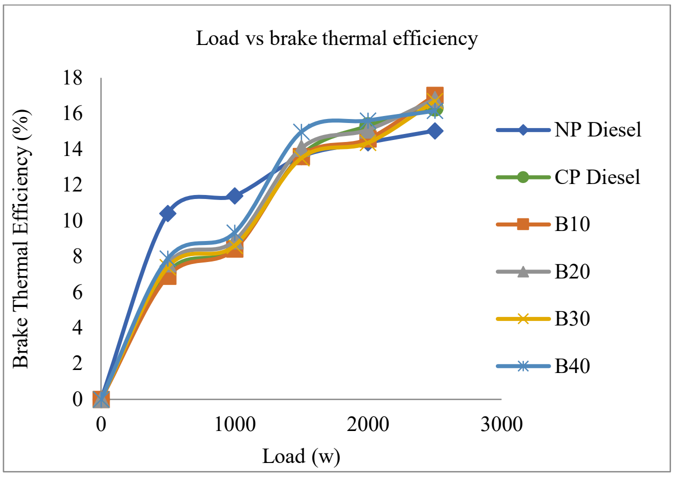

Fig 6: Variation of brake thermal efficiency with load

Fig6 shows the variation of Brake thermal efficiency with load for diesel, B10, B20, B30, B40 for coated piston and the base piston with diesel is observed. It is observed from all the above graphs at higher loads (i.e., 2500w) the Brake Thermal Efficiency for coated piston for all fuels is high. This may be due to the high temperature in the combustion chamber due to the thermal resistance of the coated piston where heat loss is minimal. It may be also because of percentage of yttria stabilized zirconia which acts as catalyst to enhance the combustion and hence efficiency of coated piston is high for all the fuels. Particularly B10 gives more Brake Thermal Efficiency than the other fuels.

The Brake thermal efficiency is found to increase by 2% for blend B10 of citronella oil, at higher load of Yttria stabilized zirconiacoated engine compared to conventional engine.

It is due to the fact that the coating material (YSZ) have low thermal conductivity, thereby providing a better insulation allowing a higher operating temperature and reducing cooling requirement which enhances the Brake thermal efficiency.

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4. Exhaust gas emissions of carbon monoxide:

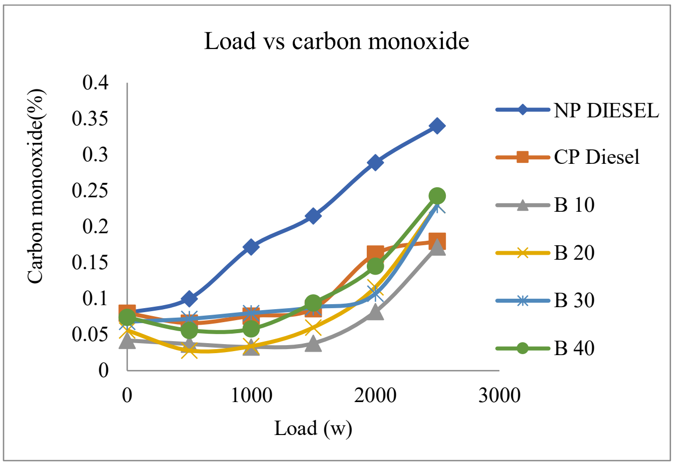

Fig 7: Load vs Carbon monoxide

From Fig 7 shows the emissions of CO with respect to load for both coated and normal piston engines. It clearly shows that CO is decreased after coating due to complete combustion. At high temperature C easily combines with oxygen and reduces CO emission.CO emission from diesel engine is related to the fuel properties as well as combustion characteristics. The carbon monoxide, which arises mainly due to incomplete combustion of the fuel, takes place in the combustion chamber. Naturally, oxygen availability is high in diesel at high temperatures so that carbon easily combines with oxygen and reduces the CO emission. The results show that CO emission of standard engine (diesel) slightly higher than YSZcoated piston engine at full load condition. There is no significant variations in the CO emission at high loads in case of all blends with YSZ coated piston. It is clearly shown that the emissions concentrations are lower than Bharath Stage III.

5. Exhaust gas emissions of carbon dioxide:

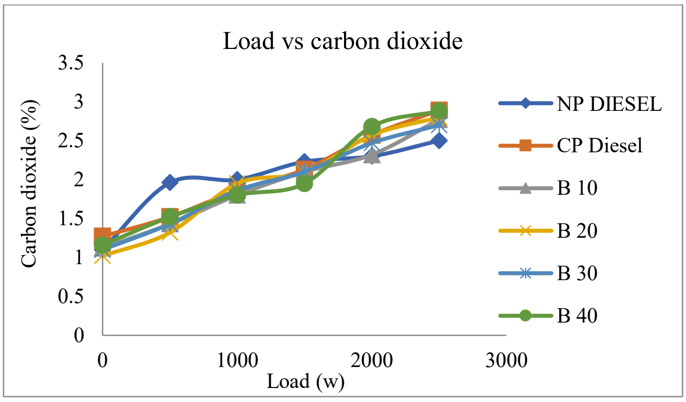

Fig 8: Load vs Carbon dioxide

As shown in Fig 8, the variation of carbon dioxide emissions with respect to load can be observed. From the above results, it is observed that the amount of CO_2 produced while using citronella oil blends are higher than diesel at full load condition, this indicates the complete combustion of fuel. Carbon dioxide from the exhaust gas for the diesel fuel (standard engine) is 2.5% vol. and for YSZ coated piston engine for different blends of citronella oil are 2.89%, 2.77%, 2.8%, 2.7% and 2.88% by vol. respectively. It is a fact that higher the carbon dioxide reading, the more efficient the engine is operating [9].

6. Exhaust emissions of hydrocarbon emissions:

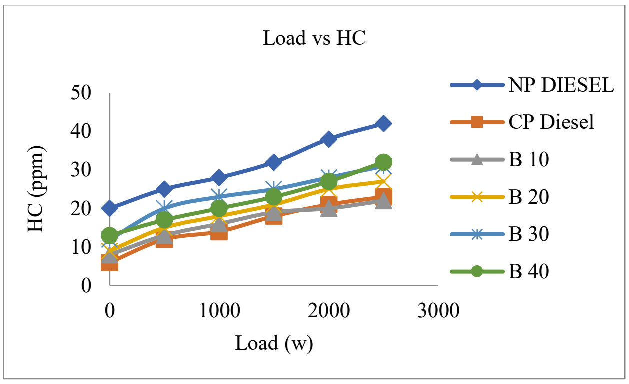

Fig 9: Load vs Hydro carbons

The measured unburned HC emissions for uncoated and coated engine pistons are shown in Fig 9.The HC emissions are reduced when the engine running with coated piston .Because at high temperature engine will have sufficient amount of oxygen which mixes with HC emissions. As a result, HC will split into H and C, which mixes with O2, thereby reducing HC emissions [10].

7. Exhaust emissions of nitrogen oxides:

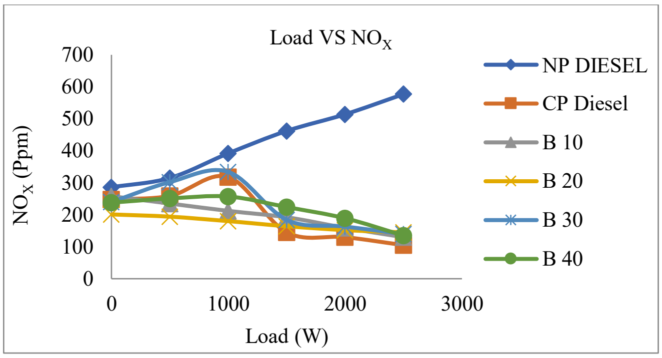

Fig 10: Load vs Nitrogen oxides

From Fig 10, the change in emissions of nitrogen oxide with respect to load for diesel, B10, B20, B30, B40 for coated piston and normal piston engine for diesel. The formation of nitrogen oxide emissions is mainly dependsup on the heat transfer rate and evaporation rate of the fuel. From the graph it is clearly shows that. Generally oxygen availability is high in diesel, so at high temperature nitrogen easily combines with oxygen, but availability of nitrogen is less due to coating and therefore forms less NO_X . It is observed that the NO_X emissions are slightly increased for with and without coating up to 60% of the load and then these emissions gradually reduces up to full load [11]. But in case of normal piston the NO_X formation is more and is gradually increases up to full load [12] [13].

VI.CONCLUSION

The present experimental work has been taken up to study the effect of ceramic coating (Yttria stabilized Zirconia) on the performance and emission characteristics of a diesel engine operated on diesel fuel and biodiesel (citronella oil) blends such as B10, B20, B30 and B40.

The performance of the engine was evaluated in terms of brake specific fuel consumption, brake thermal efficiency and mechanical efficiency. The emission characteristics of the engine were studied in terms concentration of, CO, CO_2, HC and NO_X. The results obtained for citronella oil and their blends with diesel were compared with the results of diesel.

- The BSFC is found to reduce by 0.07Kg/KW-hrfor blend B10 of citronella oil in Yttria stabilized zirconia coated engine compared to conventional engine.
- The Brake thermal efficiency is found to increase by 2% for blend B10 of citronella oil at higher load of Yttria stabilized zirconia coated engine compared to conventional engine.
- Mechanical efficiency is higher for B10 compared to normal aspirated diesel engine operation is observed.
- Lower CO emissions are produced in Yttria stabilized zirconia coated engine when compared to conventional engine.
- The coated engine has lower unburned hydro carbons emissions compared to conventional engine.
- The NO_X emissions are lower in Yttria stabilized zirconia coated engine as compared to conventional engine.
- From the above analysis it can be concluded that the citronella oil bio-diesel blends are suitable as substitute for diesel and also the Yttria stabilized zirconia coating acted as a good thermal barrier coating as they reduced emissions and improve in performance compared to conventional engine.

VII.SCOPE OF FUTURE WORK

The present work can be extended by varying the thickness of thermal barrier coating on piston crown. The engine can be tested for better performance with various alternative fuels also.

VIII.ACKNOWLEDGMENT

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