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EFFECTS OF YTTRIA STABILIZED ZIRCNIA (YSZ) COATING ON C.I ENGINE USING CITRONELLA OIL BLEND AS FUEL

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Abstract: **In addition to the rapid depletion of conventional energy supplies brought on by rising demand, diesel-based fuels are also substantial contributors to air pollution. In modern times, fossil fuels have supplied the bulk of India's energy needs. Therefore, it is time that alternative fuels for engines be sourced locally. India's rich agricultural landscape provides enough opportunity for processing a variety of oil seeds. Higher power density, better fuel efficiency, and a hotter combustion chamber are just a few of the benefits of ceramic coatings in diesel engines. Increased engine power, lower specific fuel consumption, and higher exhaust gas temperatures are all possible thanks to thermal barrier coating. Although several other systems have served as TBC, yttria-stabilized zirconia has been the focus of the majority of research. Thermal conductivity, chemical stability at the service temperature, strong thermo mechanical stability to the maximum service temperature, and the thermal expansion coefficient all play significant roles in the durability of thermal barrier coatings. Therefore, in the I.C. Engines Laboratory, a four-stroke, single-cylinder, water-cooled Diesel Engine test rig is used to compare the efficiency and emissions of diesel and various citronella oil blends utilizing a yttria-stabilized zirconia-coated piston. The performance of a diesel engine was tested using citronella oil mixes of 10%, 20%, 30%, and 40% by volume. Experimental examination of the engine is used to derive performance characteristics including brake power, specific fuel consumption, and thermal efficiency. Carbon monoxide, carbon dioxide, nitrogen oxide, and unburned hydrocarbon are only some of the emissions that are tracked.**

***Keywords*: Citronella oil, Yttria-stabilized zirconia, 4-stroke diesel engines with a single cylinder.**

I.INTRODUCTION

When it comes to transportation, power generating, marine applications, etc., diesel engines are by far the most common. As a result, diesel is in high demand, but there is a pressing need for environmentally friendly replacement fuels that may be utilized in diesel engines as the world's petroleum stocks dwindle and exhaust emissions continue to rise. As a result, renewable, environmentally friendly, and easily produced in rural areas, where there is an acute need for modern forms of energy, oils like flaxseed oil, jatropa, palm oil, sunflower oil, etc., are being considered as alternative fuels to diesel. If these fuels suit the purpose of diesel to some level they will be valuable to the rural areas in providing jobs as well as agriculture energy demands. If these fuels serve the purpose to a bigger extent they will be good substitutes in industrial, transportation etc.

Vegetable oil can be used to create bio-diesel. It burns cleanly, without producing any emissions that could be damaging to the environment. Diesel engines have better combustion when using bio-diesel rather than petroleum since bio-diesel is oxygenated. Compared to petroleum diesel, bio-diesel has less safety concerns. When bio-diesel is blended with regular diesel, emissions of harmful pollutants like carbon monoxide and particulate matter are drastically cut down.

The goal of applying ceramic coatings to the combustion chambers of diesel engines is to lower the amount of heat transferred from the cylinders to the cooling system. Advanced technology ceramics are being developed with the intention of eliminating the

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need for engine cooling systems in internal combustion engines. Removing components from the cooling system (such as the coolant pump, ventilator, water jackets, and radiators) is likely to boost engine power while decreasing engine weight and cost.

As a result of reduced detonation and noise from uncontrolled combustion, quieter engine operation is possible. Exhaust emissions are another major consideration for internal combustion engines. Ceramic coatings on internal combustion engines raise temperatures in the combustion chamber, reducing emissions of soot and carbon monoxide.

II.LITERATURE SURVEY

Researchers Zafer Utlu et al. [1] found that using used cooking oil in a diesel engine reduced CO emissions by 17.4 percent and NOx emissions by 1.45 percent while increasing smoke intensity by 22.4 percent. The use of methyl ester in place of waste frying oil reduces exhaust temperatures by 6.5%. In order to power a DI diesel engine, M.Pugazhvadivu et al. [2] heated up leftover cooking oil. Increases in BSEC and BTE, as well as decreases in CO and smoke, indicated that preheating the gasoline to 135 degrees Celsius helped lower its high viscosity. Rubber seed oil was examined by A.S. Ramadhas et al. [3], who found increased carbon deposits as a result of incomplete burning. Deepak Agarwal et al. [2007] used both heated and unheated Jatropha oil in their research, and they found that the former had lower thermal efficiency and higher BSFC and exhaust gas temperatures, respectively, than the latter and diesel. Jatropha oil produced more carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (HC), and smoke opacity than diesel. J.R. Vikram Kumar, C.J. Naveenchandran et.al [4] sought to analyse the performance and Emission characteristics of Kirloskar Diesel in the internal combustion engine by employing different mixes of Citronella Oil based biodiesel under varied Operation Conditions. The primary purpose is to establish the optimum performance of this citronella biodiesel. Recent research has focused on applying thermal barrier coatings to the piston of a diesel engine in order to improve emission characteristics and boost efficiency. Internal combustion engines have had thermal barrier coatings applied to them, specifically to the combustion chamber and cylinder lands, to make them more efficient at handling heat. Naveen. The engine was tested by P, C.R. Rajashekhar, C. Umashankar, and Vinayaka Rajashekhar Kiragi [5] using diesel and adjusting the amount of diesel to Honge bio-diesel. Then, a heat barrier coating was applied to the piston head. Al_2O_3/TiO_2 was plasma coated onto the NiCrAl basis to create the thermal coating layer. The coated piston was then put through the same kinds of tests as a non-coated piston in an unmodified engine. Titanium oxide coated pistons showed enhanced thermal efficiency and lower specific fuel consumption. $CaZrO_3$ and $MgZrO_3$ were utilised by Imdat Taymaz [6] as thermal insulation for the combustion chamber's various surfaces. Zirconia coating on the piston, cylinder head and valves improved the performance of a modified four-stroke petrol engine and altered the emission characteristics of the exhaust gas by 2% to 5%, according to research by B.M.Gnanasekaran and T.Senthilkumar [7]. Since zirconia has a low thermal conductivity, it limits the amount of heat that escapes through the cylinder's walls. As a result of the numerous chemical processes going on inside the cylinder at such high temperatures, efficiency is improved and emissions are decreased. Coating the piston improved the brake's thermal efficiency by an average of 9% and the piston's mechanical efficiency by an average of 25%. This resulted in a 7% decrease in total fuel consumption and a 6% decrease in specific fuel consumption. Coating with nitrogen-containing zirconia was shown to lower NOX emissions by 14%. Using the coated piston decreased emissions of unburned HC by 23%. At high temperatures, C readily interacts with O_2, decreasing CO emissions by 48%.

III.METHODOLOGY

Native to several regions of South and Southeast Asia and Africa, citronella grass (Cymbopogonnardus) is a fragrant tally sedge (family: Poaceae). Its primary growing regions in India are the Western Ghats (Maharashtra, Kerala), the foothills of Arunachal Pradesh and Sikkim, and the states of Karnataka, Tamil Nadu, and Tamil. Lemongrass grows wild in India and other parts of tropical Asia. There are two species of citronella grass, Cymbopogon, both of which can reach a height of 2 metres (approximately 6.5 feet) and have red stem bases. Citronella oil, extracted from these plants, is used in cosmetics, household cleaning products, and pest control products like soaps, sprays, and candles.

Cymbopogon citrates is the source of citronella oil. Myrcene, citronellal, geranyl acetate, nerol, geraniol, neral, with traces of limonene and citral, are the primary chemical components of citronella oil.

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Fig 1: Citronella plant

The grass is steamed, which releases the oil, and the oil is then distilled. The grass is cut into manageable lengths and placed in the still. When the valve on the boiler is opened, steam can enter the still under pressure. The water and citronella oil vapours enter the condenser. The distillate is collected in the separator while the distillation process continues. Since oil is less dense than water and does not mix with it, it floats atop the separator, where it is continuously drained. The oil is filtered after being decanted. Oil is usually kept in glass or well-tinned iron containers. Because air and light can degrade oil, it's important to completely fill containers.

B. The trans esterification method is the most common one. In the presence of a catalyst, the oil extracted from the seeds is combined with an appropriate alcohol to undergo a chemical reaction. Glycerol and alkyl esters are the end results of this reaction. Biodiesel refers to the resulting alkyl esters. In general, the catalysts employed for Trans esterification process can be bases, acids or immobilised enzymes. For the Trans esterification to achieve a good yield, the alcohol should be free of moisture and the free fatty acid level must be <0.5%. Although the reverse reaction of trans esterification is possible, it is not significant in the biodiesel synthesis process since the glycerol generated is immiscible with the product, resulting in a two-phase system. After the reaction has been completed, glycerol is removed from the alkyl esters. Glycerol is easily separated from the esters due to its low solubility in the esters; this can be done through settling or centrifugation. After transesterification is complete, water is added to the reaction mixture to further facilitate the separation of glycerol. After separating glycerol, the alkyl esters go through a neutralisation stage, during which excess alcohols are removed and the product is washed in water. To remove any trace of the catalyst and separate any soap that may have formed during the reaction, acids will be added to the final biodiesel product. When soaps react with acids, they release free fatty acids and water-soluble salts. The biodiesel will retain its free fatty acids after going through a water washing process, but the soluble salts will be washed away. Washing biodiesel in water that has been neutralised first minimises the amount of water required and eliminates the possibility of emulsion formation. The amount of water in fats or oils, the reaction temperature, the catalyst, the amount of time the reaction takes, and the amount of fatty acids are all factors in the trans esterification process.

C.Plasma spray coating process:

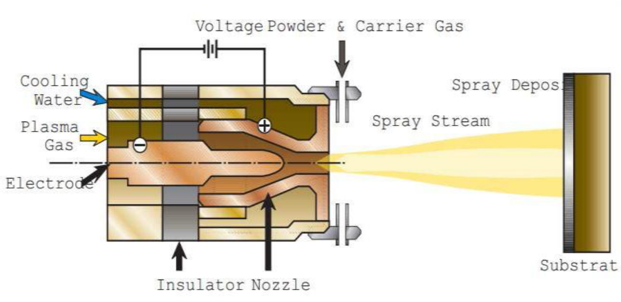

Fig 2. Schematic diagram of plasma spry technique

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Procedure:

A cathode and the spray gun's concentric nozzle create an electric arc. The arc ionises the gas mixture flowing rapidly along the electrode, turning it into plasma. Powdered Yttria-stabilized zirconia coating material is injected into the plasma jet before it is released from the nozzle. The particles are rapidly melted and accelerated by the plasma jet's heat and velocity, and then driven to form a coating on the substrate with a thickness of 0.2 mm.

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

IV.EXPERIMENTAL WORK

The efficiency and emissions of internal combustion engines were the focus of an experimental setup. The piston crown in this study was coated with Yttria-stabilized zirconia (YSZ), and citronella oil was used as a biofuel. The test vehicle was a direct injection diesel engine with a single cylinder and water cooling. One of the best instruments for measuring electrical loads is an eddy current dynamometer. The engine's specs are listed in Table-1 below.

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

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Rated power	5HP
Starting	Hand start with crank handling
Type of cooling	Water cooled

IV. Results And Disscussions

We measured the engine's effectiveness by looking at how much gasoline was used to brake, how much heat was generated, and how efficient the brakes were. Results obtained for citronella oil mixes with YSZ coated piston are compared with the results of pure diesel to determine the engine's emission characteristics in terms of concentration of CO, HC, and NOX.

1. Brake specific fuel consumption:

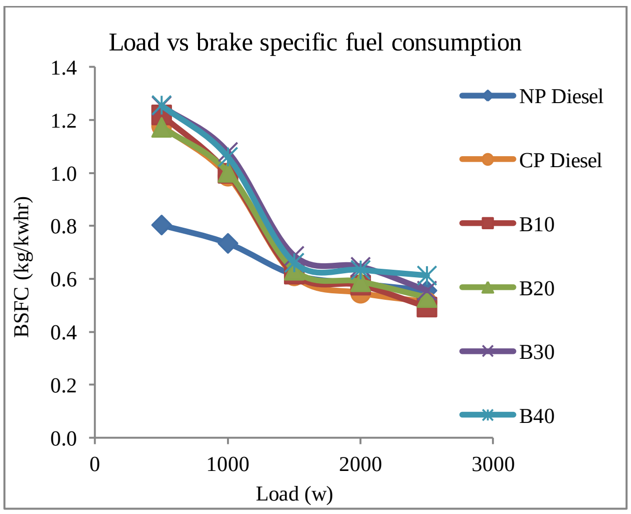

Fig 4: load vs. Brake specific fuel consumption

In fig. 4, we see the outcome for how the brake specific fuel consumption (BSFC) changes depending on the load. Diesel, B10, B20, B30, and B40 show load-dependent variations in brake specific fuel consumption. The preceding graphs show that the coated piston, B10 blend, and B20 blend all have higher B.S.F.C values than do uncoated pistons. Because of the high temperatures in the combustion chamber made possible by the thermal resistant coating, and because the composition of yttria stabilised zirconia acts as a catalyst to enhance combustion, yttria stabilised zirconia coated pistons use less fuel. When compared to the other fuels, B10 and B20 blends have a poor BSFC, especially at a load of 2500W. Blend B10 of citronella oil in a Yttria-stabilized zirconia-coated engine reduces BSFC to 0.07Kg/KW-h, a significant improvement over conventional engines. Since the heat barrier coatings appear to be so effective, it follows that the use of brakes with lower specific fuel consumption would benefit greatly from their application. It's mostly because the combustion chamber gets hotter.

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2. Mechanical efficiency:

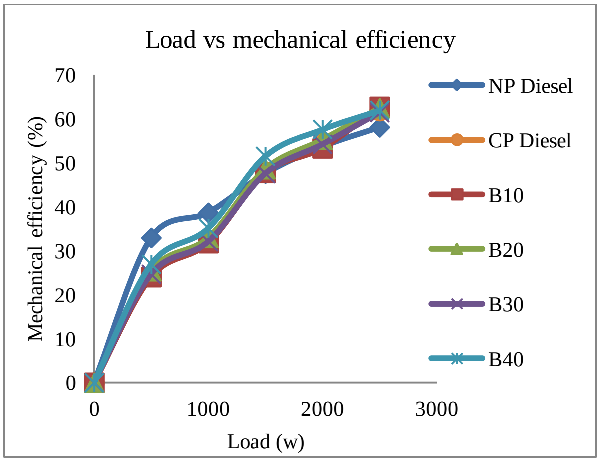

Fig5: Variation of mechanical efficiency with load

Fig.5 shows how mechanical efficiency varies as a function of load. Diesel, B10, B20, B30, and B40 engines with YSZ coated pistons show 61.8%, 62.5%, 62.45%, 61.44%, and 61.97% mechanical efficiency at maximum loads, respectively. Compared to a standard piston running on diesel (58.08%), the mechanical efficiency of a piston with a coating is higher throughout the board. Particularly the B10 fuel delivers better mechanical efficiency than the other fuels. Based on these findings, it is clear that the piston coating significantly reduces heat loss, leading to a very hot combustion chamber.

3. Brake thermal efficiency:

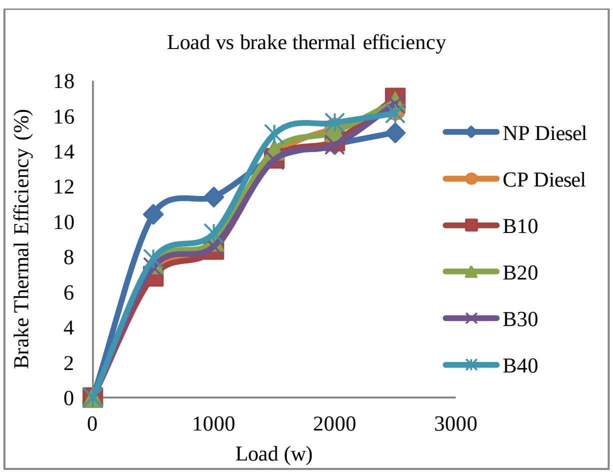

Fig 6: Variation of brake thermal efficiency with load

The thermal efficiency of the brakes changes as the load increases or decreases in Fig. 6 for diesel, B10, B20, B30, and B40 for coated piston and the base piston. Brake Thermal Efficiency for coated piston for all fuels is observed to increase with increasing load (i.e. 2500w) across all graphs. Because of the coated piston's thermal resistance, when heat loss is minimal, the combustion chamber may be extremely hot. It's possible that the high efficiency of coated pistons for all fuels is due to the presence of a catalyst comprised of yttria-stabilized zirconia. Brake Thermal Efficiency is highest with B10 among the fuels available.

At higher loads, Yttria-stabilized zirconia-coated engines with brakes show a 2% improvement in thermal efficiency compared to conventional engines running on blend B10 of citronella oil.

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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.

It is due to the fact that the coating material (YSZ) have low thermal conductivity, consequently providing a better insulation allowing a greater operating temperature and decreasing cooling requirement which boosts the Brake thermalefficiency.

4. Exhaust gas emissions of carbon monoxide:

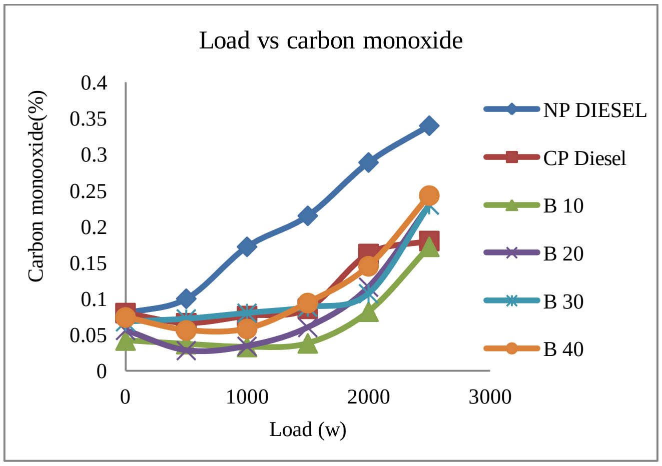

Fig 7: Load vs Carbon monoxide

Figure 7 displays the CO emissions from coated and standard piston engines as a function of load. It's undeniable proof that complete combustion after coating reduces CO levels. CO emission from a diesel engine is connected to the properties of the fuel and the characteristics of combustion. At high temperature C quickly combines with oxygen and lowers CO emission. Incomplete combustion of the fuel is the primary source of the carbon monoxide produced in the combustion chamber. Because carbon readily interacts with oxygen at high temperatures in diesel, the combustion byproduct carbon monoxide is diminished. CO emissions are somewhat greater in a conventional engine (diesel) at full load compared to those in a YSZcoated piston engine, as shown by the data. When using a piston that has been coated with YSZ, no mix significantly differs from the others in terms of CO emission under heavy loads. It is demonstrated without reasonable doubt that the concentrations of emissions are less than those of Bharath Stage III.

5. Exhaust gas emissions of carbon dioxide:

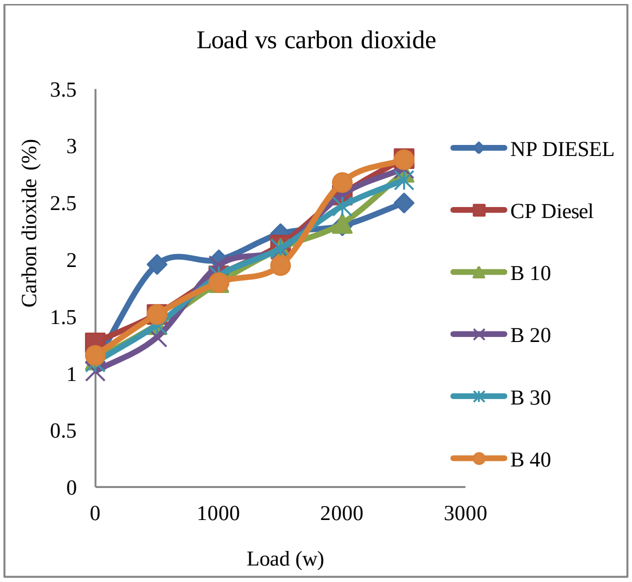

Fig 8: Load vs Carbon dioxide

Carbon dioxide emissions vary depending on the load, as depicted in Fig. 8. It can be seen from the data above that under full load conditions, the amount of CO2 created while using citronella oil blends is more than when using diesel, indicating complete fuel combustion. The conventional diesel fuel engine emits 2.5% vol. of carbon dioxide in its exhaust stream. Also, the various citronella oil mixtures work best with a YSZ coated piston engine at a vol. respectively. The higher the carbon dioxide reading, the better the engine is doing.

6. Exhaust emissions of hydrocarbon emissions:

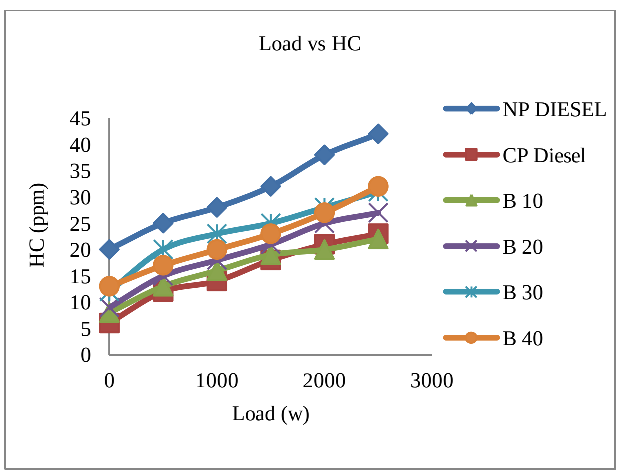

Fig 9: Load vs Hydro carbons

Fig. 9 displays the measured unburned HC emissions for uncoated and coated engine pistons. The HC emissions are reduced when the engine is running with coated piston, since more oxygen is available to mix with the emissions at higher temperatures. Therefore, HC will decompose into H and C, which will combine with O2 to lessen HC emissions.

7. Exhaust emissions of nitrogen oxides:

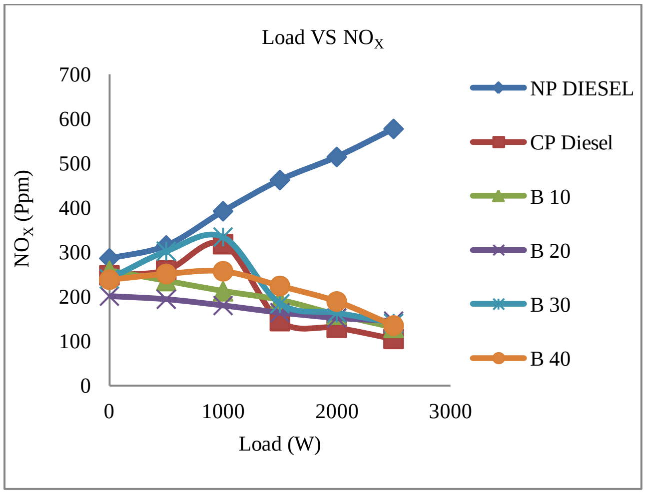

Fig 10: Load vs Nitrogen oxides

If you look at Fig. 10, you can see how the NOx emissions from a diesel B10, B20, B30, or B40 engine fluctuate as a function of load. Emissions of nitrogen oxides are highly sensitive to the fuel's evaporation and heat transfer rates. This is evident from the graph. Generally oxygen availability is high in diesel, thus at high temperature nitrogen easily combines with oxygen, but availability of nitrogen is less owing to coating and hence creates less NOX. It has been observed that NOX emissions rise somewhat for both with and without coating up to 60% of the load, before levelling off and then disappearing altogether at full load. However, NOX generation is greater in the case of normal piston and grows steadily up to full load.

VI.CONCLUSION

Using a diesel engine running on diesel fuel and biodiesel (citronella oil) mixes of B10, B20, B30, and B40, the current experimental work investigates the impact of ceramic coating (Yttria stabilised Zirconia) on performance and emission characteristics.

- We measured the engine's effectiveness by looking at how much gasoline was used to brake, how much heat was generated, and how efficient the brakes were. Concentrations of CO, CO2, HC, and NOX were measured to learn about the engine's emission characteristics. Citronella oil and diesel blends were tested, and the results were compared to those of diesel alone. 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 BSFC is observed to lower by 0.07Kg/KW-hr for blend B10 of citronella oil in Yttria stabilised zirconia coated engine compared to traditional engine.

  At greater loads, Yttria-stabilized zirconia-coated engines using blend B10 of citronella oil show improved thermal efficiency compared to non-coated engines.

  It has been discovered that B10 mechanical efficiency is higher than that of normally aspirated diesel engines.

- When compared to a standard engine, the CO emissions from one covered with Yttria-stabilized zirconia are significantly lower.
  The coated engine produces fewer emissions of unburned hydrocarbons.

Based on the results presented above, it is clear that citronella oil bio-diesel blends are an effective diesel replacement, and that the Yttria-stabilized zirconia coating serves as an efficient thermal barrier.

VII.SCOPE OF FUTURE WORK

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Changing the depth of the thermal barrier coating on the piston crown will allow for further development of the work shown here. The engine can be tested for better performance with other alternative fuels also.

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