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Performance Evaluation On A Four Stroke CI Engine With Yttria Stabilized Zirconia (YSZ) Coated Combustion Chamber Of Different Thickness With Hazelnut Bio-Diesel Blend As Fuel

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***Abstract*: *Paper A comparative experimental analysis was carried out on a 4-stroke single cylinder, vertical, water cooled, Compression Ignition engine with combustion chamber coated with Yttria Stabilized Zirconia(YSZ) of two different thickness like 0.05mm and 0.2mm with hazelnut Bio-Diesel blend HBD20(20% hazelnut Bio-Diesel and 80% Diesel by volume)as fuel. Experimental trials were carried out with the above bio-diesel blend as fuel operated in the ceramic coated engine working at all loads from minimum to maximum. A comparative analysis was made with the results obtained from experimental trials conducted on ceramic coated engine with two different thickness fuelled with HBD20 as fuel and conventional engine with normal diesel as fuel. Parameters selected for comparison are, exhaust emission characteristics like NOx emissions, CO emissions, smoke density, and total and partially unburned HC emissions and performance parameters like brake specific fuel consumption (BSFC), brake Thermal efficiency (BTHE), and exhaust gas temperatures (EGT). In this work engine coated with Yttria Stabilized Zirconia(YSZ) of 0.2mm thickness is showing better performance than engine with combustion chamber coated with 0.05mmthickness and also showing almost equal performance when compared with conventional engine with normal diesel as fuel in performance parameters and considerable decrease in exhaust emissions like carbon monoxides (CO), hydro carbons (HC) and slight increase in oxides of nitrogen (NOx). Yttria Stabilized Zirconia(YSZ) ceramic coated engine with 0.2mm thickness fuelled with Bio-diesel blend HBD20 prepared from hazelnut bio-diesel showing almost equal performance when compared with conventional engine with diesel as fuel in the present work.*

Keywords* : *Yttria Stabilized Zirconi, hazelnut, Bio-Diesel HBD20, BTHE

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I. INTRODUCTION

In automotive industry engines running with diesel as fuel are playing a predominant role. These are having immense importance in Transportation, electricity and agriculture sector due to its minimal maintenance and running expenses and fuel savings. An accountable amount of heat is consumed by exhaust gases and coolant, generated through combustion process. Only 30 to 40% of developed heat in CI engines will become in to mechanical work. The purpose of the cooling system is to carry out the excess heat to surroundings, generated due to friction and combustion process. (G. Sivakumar, 2014)[1]. There is massive demand for IC engines from the industry, Irrespective of ongoing hikes in the fuel price. This motivates the experimenter to examine continuously for minimizing the emission characteristics and elaborating the performance of IC engines. To enhance the efficiency of an IC engine, now a days many researchers are using Thermal barrier coatings to sustain heat developed in combustion process in the combustion chamber. Normally Ceramic coatings are not only prevents shocks and fatigue developed in the parts of combustion chamber but also works as the source of heat resistance and supports to reduce the emission levels of hydrocarbons and carbon monoxide. The dissipation of heat from combustion chamber to the surroundings through cooling system can also be reduced by coating thermal barrier materials on the parts of combustion chamber (Assanis, 2012)[2], which supports the engine for better combustion of air and fuel mixture. Exhaust gas temperatures increases relatively due to rise in the after combustion temperature. In recent years huge amount of research is available to explain about advantages of ceramic coatings utilization in IC engines theoretically, but the analysis based on experimentation is very less. Normally the components of engine like valve seats, valves, piston crown and cylinder liners by choice are coated using thermal coatings to modify normal engine in to LHR (low heat rejection) engine. The majority of researchers are came to an end with that there is significant development in the BTHE (brake thermal efficiency) and small decrease BSFC (brake specific fuel consumption) of TBC (Thermal Barrier Coated) engines when compare with conventional engine (Pankaj N. Shrirao, 2011) [3].

In this work an approach was made to increase the efficiency of CI engine by using esters of vegetable oil as fuel. Hence by modifying piston geometry and by using LHR concept in this work palm stern methyl ester is used as fuel. The experimental trails were carried out
over a single cylinder four stroke diesel (CI) engine with 5.2 kW. To modify the conventional engine into ceramic coated engine, partially stabilized zirconium PSZ of 0.5 mm thickness is coated over the piston crown. From the analysis of results it is noticed that the piston with modified geometry in LHR engine has given considerably best performance of all around (S. Venkata Lakshmi, 2014) [4]. In the present investigation, bio-diesel from methyl esters was prepared from hazelnut soap stock or waste sunflower oil blend using methanol, sodium hydroxide and sulphuric acid in a two phase process. The outcomes of methyl ester conjoined with Diesel used as a fuel in the IDI (indirect injection) Diesel engine were tested at both Partial and full loads for its performance and emissions of a 4-cylinder, 4-stroke, turbocharged engine. The experimental outcome unveiled that hazelnut soap stock/waste sunflower oil methyl ester can be used as substitute for Diesel fuel partially at almost all working conditions with respect to emissions and parameters of performance without pre-heating of blended fuel and making any medications in the conventional engine (E.Ozturk, 2005)[5]. The engine's performance was studied for both wet ethanol and diesel with and without Zirconia coating. Also the emissions values are recorded to study the engine's behavior on emissions. Satisfactory performance was obtained with Zirconia coating compared with a standard diesel engine. The brake thermal efficiency was increased up to 1.64% for ethanol with coating and there was a significant reduction in the specific fuel consumption. The NOx, CO and HC emissions in the engine exhaust decreases with coating. Conclusion: Using ethanol as sole fuel for a LHR diesel engine causes an improvement in the performance characteristics and significant reduction in exhaust emissions (Lawrence, 2011)[6]. The investigations were conducted at different loads like Zero, quarter, half, three quarter and at maximum loads, to compare the obtained results. The experimental statistics unveiled that brake power and brake thermal efficiency values of LHR (Low heat rejection) engine turned out to be moderately larger when compared with normal diesel engine. It also noticed that there is reduction in heat loss to coolant and increase in heat content in the exhaust gases for LHR (Low heat rejection) engine when compared with normal diesel engine with single cylinder. Emissions such as HC and CO are decreased and there is increase in NOx in LHR(low heat rejection) Engine when compared with normal engine (Shaikh, 2015)[7]. To reduce the heat losses to coolant, an attempt was made to investigate a LHR (low heat rejection) engine. Due to insulated piston and cylinder in TBC engines there will be effective utilization in heat generated during combustion process. The intake cam structure was modified for delayed closing of inlet valve, to decrease losses due to blow down, and also to increase the BTHE(brake thermal efficiency) a concept of extended expansion was also amalgamated to extend thermal efficiency (Kumar, 2013)[8]. The influence of ceramic coating on the turbocharged engine running with diesel as fuel was investigated for its performance, emissions and energy balance. To achieve this valves, piston and cylinder head of engine are coated with YSZ (yttria stabilized zirconia) layer with 0.35 mm thick and nickel-chromium aluminum bond coat of 0.15mm thick by using plasma spray coating method Then, engine was tested under peak load conditions (Ciniviz, 2009)[9]. In this paper a review was made in the characterization and production of oil from vegetable and also performing experimental work in this field all over the globe and it is clearly described about the research in these areas and challenges encountered (Ramadhas, 2003).

II. PROCEDURE

A. Experimental Set up

A test rig was framed to analyze performance and emission parameters of an engine with insulated combustion chamber, provided with knurling on piston head fuelled with hazelnut bio-diesel blend HBD20 as fuel. In this work it is aimed to conduct number of test runs on the developed test rig to judge the performance and emission parameters of a bio-diesel at different operating conditions and to compare the results with normal engine operating on Diesel.

B. Description of Experimental setup

The set-up (Plate 3.1) comprises of a Mono cylinder, 4 stroke, constant, 1500 rpm speed, 661cc, direct injection, Kirloskar make (model – TV1), Diesel Engine assembled with eddy current dynamometer shown plate3.2. Engine can start with hand cranking by operating decompression lever. With the help dynamo meter, load was applied. Changing of load engine was done by controlling the current developed from dynamometer connected to the electromagnets. Calibrated Digital PT100 type of temperature sensors were utilized for the measurement of temperature. Control panel (Plate-3.3) which is provided with digital display meters for collecting water inlet and outlet temperatures supplied as coolant to the engine, inlet and outlet temperatures of water supplied to the calorimeter, temperature of exhaust gases from engine entering into calorie meter and coming out from calorimeter, rotameter for measuring the quantity of water supplied to the calorimeter and engine, switch to apply load and an indicator to find speed of the engine.

Table 1: Technical Specifications of Experimental Test Rig

Component	Description
Engine	Type - single cylinder, four stroke Diesel, water cooled, rated power 3.7 kW at 1500 rpm, stroke 110 mm, bore 87.5 mm. 661 cc,
Dynamometer	Type eddy current, air cooled, with loading unit
Temperature sensor	Calibrated Digital PT100
Load indicator	Digital, Range 0-50 kg, Supply 230 VAC
Rotameter	Engine cooling 40-400 lph; Calorimeter 25-250 lph
Exhaust gas analyzer	AVL five gas analyzer
Smoke meter	AVL 437-smoke meter

From the set-up the performance of engine based on the parameters like Brake Power,

Brake Thermal Efficiency, consumption of fuel, volumetric efficiency, heat balance and air-fuel ratio etc can be find out. A fuel tank was designed with suitable option to refill fuel and an outlet for fuel supply to the engine. Consumption of Fuel was measured by using a calibrated piezometer with a three way regulating value. An air box with an orifice, assembled with U tube manometer is used to measure consumption of air and required data was collected in the balanced position of engine.

Figure: 1 Experimental Setup

III. RESULS AND DISCUSSIONS

While presenting all the performance parameters and exhaust emissions throughout the study all the readings of normal engine and modified engine are shown in the graph. And comparison of results for modified engine with bio-diesel blend is made at three fourth of the rated load with normal engine with diesel as fuel. Experiments were carried out with YSZ ceramic coated engine with varying thickness viz 0.05mm and 0.20mm to investigate performance parameters and constituents of exhaust emissions with hazelnut bio-diesel blend HBD20 as fuel.

A. Brake Thermal Efficiency

From the figure 2 it is observed that maximum Brake Thermal Efficiency is obtained at three fourth load because of effective combustion and low frictional losses of the engine at this load. The results of Brake Thermal Efficiency of this engine with ceramic coated thickness 0.2mm at low load, medium load, three fourth load and at maximum load is 14.3%, 25.78%, 30.98% and 28.59% respectively.

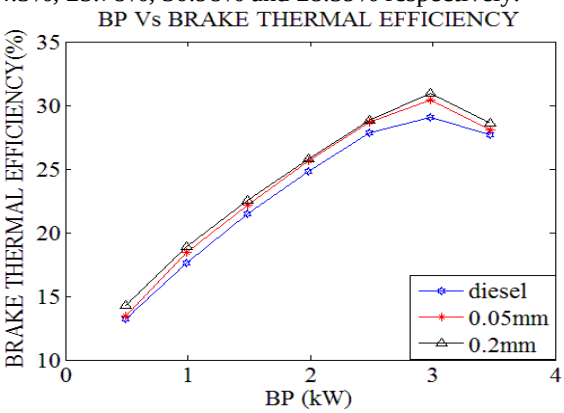

Figure: 2 BTHE of an engine with hazelnut bio-diesel HBD20 as fuel

The Brake Thermal Efficiency at three fourth loads for the engine with ceramic coated combustion chamber of thickness 0.05mm 0.2mm are 29.38% and 30.98% respectively and for diesel as fuel in conventional engine at same loads it is 29.0213%.

B. Brake Specific Fuel Consumption (BSFC)

From the figure 2 it is shown that the results of Brake Specific Fuel Consumption of 0.2mm thickness ceramic coated engine at low load, medium load, and three fourth load and at maximum load are 0.603kg/kWhr, 0.323kg/kWhr, 0.275kg/kWhr, 0.285kg/kWhr respectively.

The Brake Specific Fuel Consumption at three fourth loads for the engine with ceramic coated combustion chamber of thickness 0.05mm and 0.2mm are 0.31kg/kWhr and 0.275kg/kWhr respectively and for diesel as fuel in conventional engine at same load it is 0.284kg/kWhr.

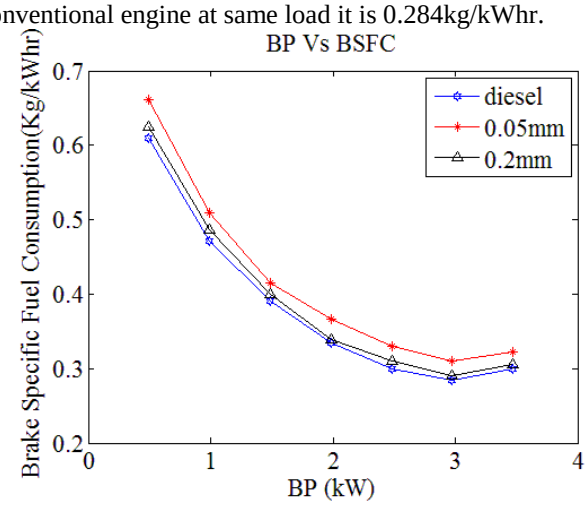

Figure: 3 BSFC of an engine with hazelnut bio-diesel HBD20 as fuel

C. Exhaust Gas Temperatures (EGT)

Exhaust Gas Temperatures (EGT) of YSZ ceramic coated engine with varying thickness by using hazelnut bio-diesel blend HBD20 as fuel is higher than the conventional Diesel engine with Diesel as fuel.

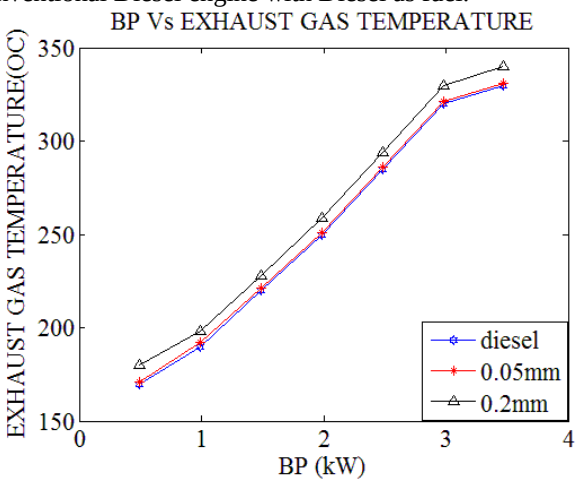

Figure: 4 EGT of an engine with hazelnut bio-diesel HBD20 as fuel

The results of Exhaust Gas Temperatures at low loads, medium loads, three fourth
loads and at maximum loads for 0.2mm thickness ceramic coated engine are 1800C, 2590C, 3300C, and 3400C respectively. The Exhaust Gas Temperatures at three fourth loads for the engine with ceramic coated combustion chamber of thickness 0.05mm, and 0.2mm are 3210C and 3300C respectively and for diesel as fuel in conventional engine at same load it is 3200C.

D. Carbon Monoxide Emission (CO)

Carbon Monoxide Emission (CO) of ceramic coated engine with thickness 0.2mm operated with blend HBD20 as fuel is lower than the conventional engine with Diesel as fuel at all loads and it is also increasing along with load. The results of Carbon Monoxide at low loads, medium loads, three fourth loads and maximum loads are 0.45ppm, 0.51ppm, 0.61ppm and 0.68ppm respectively. The results of Carbon Monoxide at three fourth loads for the engine with ceramic coated combustion chamber of thickness 0.05mm and 0.2mm are 0.64ppm and 0.61ppm respectively and for diesel as fuel in conventional engine at same load it is 0.75ppm.

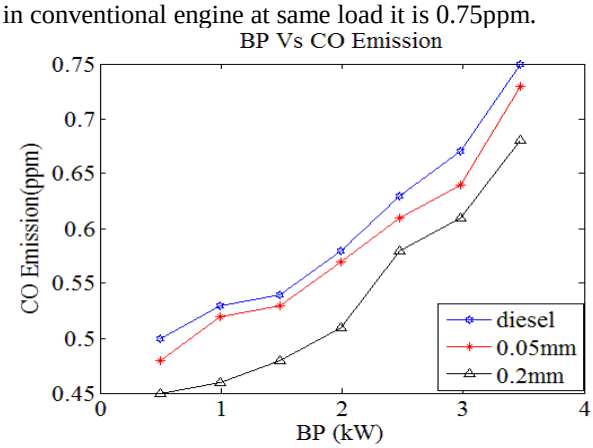

Figure: 5 CO emission of an engine with hazelnut bio-diesel HBD20 as fuel

E. HC Emissions (HC)

Hydro Carbon Emission (HC) of ceramic coated engine with thickness 0.2mm operated with blend HBD20 as fuel is lower than the conventional engine with Diesel as fuel. The results of Hydro Carbon Emission at low loads, medium loads, three fourth loads and maximum loads are 39ppm, 58ppm, 67ppm and 69ppm respectively.

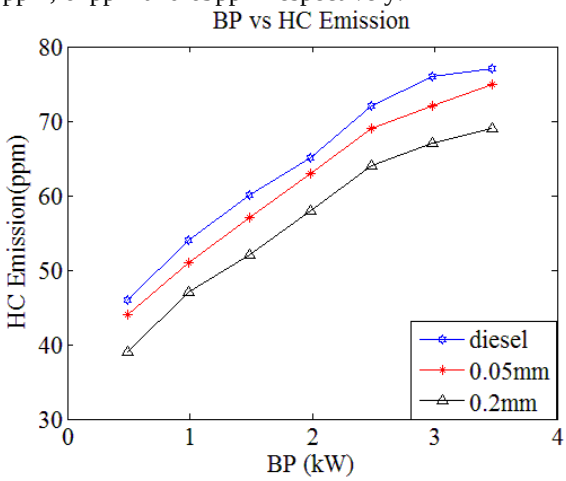

Figure: 6 HC emission of an engine with hazelnut bio-diesel HBD20 as fuel

The results of Hydro Carbon Emission at three fourth loads for the engine with ceramic coated combustion chamber of thickness 0.05mm and 0.2mm are 72ppm, 67ppm respectively and for diesel as fuel in conventional engine at same load it is 76ppm.

F. NOx Emissions

NOx Emission of ceramic coated engine with thickness 0.2mm operated with blend HBD20 as fuel is higher than the conventional engine with Diesel as fuel.
The results of NOx at low loads, medium loads, three fourth loads and maximum loads are 544ppm, 658ppm, 708ppm and 719ppm respectively. The results of NOx Emission at three fourth loads for the engine with ceramic coated combustion chamber of thickness 0.05mm and 0.2mm are 694ppm, and 708ppm respectively and for diesel as fuel in conventional engine at same load it is 690ppm.

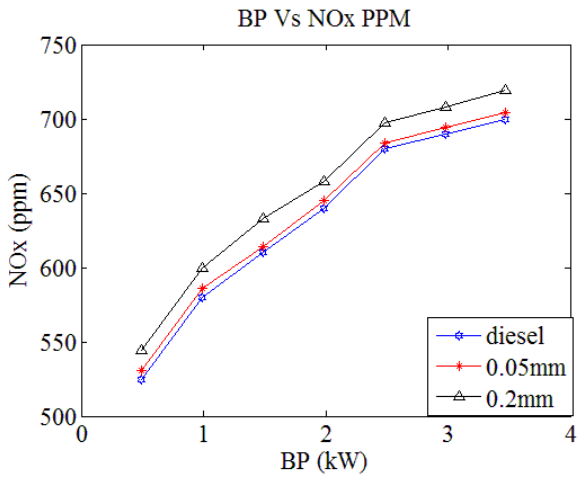

Figure: 7 NOx emission of an engine with hazelnut bio-diesel HBD20 as fuel

IV. CONCLUSION

In this work the investigation was carried out for the evaluation of modified engine with HBD20 as fuel based on the performance parameters and exhaust emissions, based on this the important conclusions observations drawn are as follows:

1. It is observed that four stroke, single cylinder, Diesel engine actually designed to run on diesel as fuel is successfully operating with Hazelnut biodiesel Blend HBD20 as fuel without any constructional modifications. The blend HBD20 is showing better performance than other blends tested in the present research work.
2. From the results obtained it is concluded that Yttria Stabilized Zirconia can be successfully used as coating material to apply on combustion chamber. Among all thicknesses applied on the combustion chamber listed in the work, 0.2mm ceramic coating thickness is giving best performance in all aspects tested.
3. It is observed that engine with 0.2mm thickness YSZ ceramic coated combustion chamber and provided with knurled piston operating on HBD20 blend as fuel is having the following results which are better than conventional engine with normal diesel as fuel.

- ✓ The percentage increase in BTHE of modified engine with HBD20 blend as fuel is 6.7% when compared with engine operated on Diesel as fuel.
- ✓ The percentage decrease in BSFC of modified engine with HBD20 blend as fuel is 3.16% when compared with engine operated on Diesel as fuel.
- ✓ The percentage increase in EGT of modified engine with HBD20 blend as fuel is 3.12% when compared with engine operated on Diesel as fuel.
- ✓ The percentage decrease HC Emission of modified engine with HBD20 blend as fuel is 18.66% when compared with engine operated on Diesel as fuel.
- ✓ The percentage decrease in CO Emission of modified engine with HBD20 blend as fuel is 11.8% when compared with engine operated on Diesel as fuel.
- ✓ The percentage increase in NOx emission of modified engine with HBD20 blend as fuel is 2.6% when compared with engine operated on Diesel as fuel.

Finally From this investigation it is concluded that engine with 0.2mm thickness YSZ ceramic coated combustion chamber provided with knurled piston operating on hazelnut bio-diesel blend HBD20 as fuel is showing better performance than conventional engine with normal Diesel as fuel. A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

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