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PERFORMANCE AND EMISSION CHARACTERISTICS OF YSZ THERMAL BARRIER COATED PISTON WITH VARIABLE EGR RATES AND RAPESEED OIL AS FUEL

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ABSTRACT

The decreasing deposits of petroleum reserves and increasing risk of environmental pollution which is devastating the flora and fauna has become biggest concern. In order to address this one of the solutions is using alternate fuels which decreases the risk and is driving the researchers for a better biodiesel. This work is aimed at analysing the performance and emission characteristics of YSZ thermal barrier coated piston on Rapeseed oil B100 with EGR. It was found that at peak load conditions the emission of CO, CO_2 and HC increases whereas the NOx emission decreases which sustains the functionality of EGR. By varying the rates of EGR i.e. 10%, 15% and 20% on coated piston for 20% at full load condition the maximum NOx reduction is observed.

Key words: YSZ Thermal Barrier Coating, Rates of EGR, Rapeseed Oil and Biodiesel

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1. INTRODUCTION

The concept of alternative and renewable energy is driving the researchers in different directions to save not only the available natural fossil fuels for the future generations but also to provide new technological advancements in renewable energy. Out of all different types of renewable energy sources the biodiesel has become one of the most prominent and promising in automobile industry. Dated back to World War-II the search on biodiesels has been initiated but it has become more necessary in the recent years. There is a huge work done by many researcher and are doing on these biodiesel with different raw materials and different blends.

Many studies have shown that biodiesel will bring about the reduction of soot, HC and CO emissions, due to its oxygen content [1–5]. The source of raw material of biodiesel is extensive and abundant, such as animal and vegetable fats and oils [6]. The cetane number of biodiesel is high, which makes combustion process smoother [7]. Biodiesel does not contain aromatics, and Sulphur content of it is very low. And it is non-toxic and easily degradable [8]. In the process of production and utilization of biodiesel, the net accumulation of CO in the atmosphere is near zero, which will help to reduce the greenhouse effect and keep the positive cycle of ecological environment. The oxygen content in the biodiesel and the shorter combustion delay caused by high cetane number promote the combustion process, which increases the indicated thermal efficiency [9]. However, the increase of NOx emissions brought about by the oxygen content in biodiesel cannot be ignored [10–12].

Rapeseed is one of such raw materials being tested for biodiesels. Now a days Rapeseed is gaining market in this sector as one of the best biodiesels in comparison with other biodiesel and blends. Whichever is the fuel that is used in the engines the most important thing that has to be considered is the emission regulations. With the usage of biodiesel, the emissions like HC, CO, NOx and sooth gets reduced which favours the improved environmental conditions. Cheng Tung Chong et. al. in their work on combustion spray characteristics of Rapeseed oil found that it is similar to that of Diesel [13]. Mohanad Aldhaidhawi et. al. in their review on combustion and emission characteristics of Rapeseed oil observed that the emission of particulates, CO and HC are lower whereas the emission of CO2 and NOx is higher than the diesel [14].

M. G. Bannikov et. al. in their experimentation on Jatropha Methyl Esters and diesel found the following variations: (1) engines fuelled with Jatropha Methyl Esters at high loads had increased specific fuel consumption, reduced NOx, unburned HC and smoke emissions, (2) increase in specific fuel consumption is because of lower heating value of the fuel, and (3) the analysis of combustion characteristics also revealed that the cetane index measured by ASTMD976 is not a proper measure for ignition quality of the fuel [15]. Bhaskar Kathirvelu et. al. in their experimentation on Jatropha and fish waste found that without major modifications to the diesel engine the emission of CO, unburned HC and soot is less but there is a slight increase in NOx at all loading conditions [17]. Rajneesh Kumar et. al. in their experimentation found that blends of Jatropha Ethyl Esters and diesel can be successfully used in diesel engines without any modifications to the engines, with superior performance and emission characteristics [16]. Venkateswarulu Chintala et. al. in their work on solar driven Jatropha biomass pyrolyzed oil on direct injection diesel engines found the following characteristics in performance and emission: (1) efficiency of the engine increased for PODB20 blends from 32% to 34% and whereas for PODB40 blends it was 35.6%, (2) there is a reduction of emission of HC, CO and smoke with both PODB20 & PODB40, whereas the emission of NOx first increased then it decreased [18].

To reduce the emissions and to meet the norms one of the alternative is usage of Exhaust Gas Recirculation system commonly called EGR. Ozer Can et. al. in their work on combined effect of soybean biodiesel with different EGR rates found that at 5% and 10% EGR rates there is no significant effect on engine performance but there is a slight increase in brake specific fuel consumption and 3% reduction in brake thermal efficiency. At high engine loads there was a significant improvement in NOx and smoke emission up to 55% and 15% are achieved [19]. Maqdam Tariq Chaichan in his work on performance, emission and combustion characteristics of CIE using hydrogen, biodiesel and massive EGR found that increase of hydrogen increased NOx emission and high EGR rates reduces brake thermal efficiency. The reduction in NOx emission depends on EGR ratios and supply of hydrogen [20]. B. Rajesh Kumar et. al. in their work on effect of EGR on DI engine with Pentanol and diesel blends found that increasing the EGR rates decreased NOx emission, for medium load it is around 41% and for high loads it is around 33.7% reduction [21]. L. Labecki et. al. in their work on injection parameters and EGR on combustion and emission characteristics of Rapeseed oil and blends found that addition of 10% and 20% EGR does not show any significant effect on in cylinder pressure. It was also found that highest amount of NOx reduction was absorved for 100% Rapeseed oil as a fuel and a significant reduction of NOx upto 60% for 20% EGR was absorved [22-].

2. EXPERIMENTAL SETUP

The setup consists of single cylinder with piston 100% Yttria-Stabilized Zirconia (YSZ) thermal barrier coatings, four stroke diesel engine is connected to eddy current type dynamometer for loading as shown in Figure. 1.

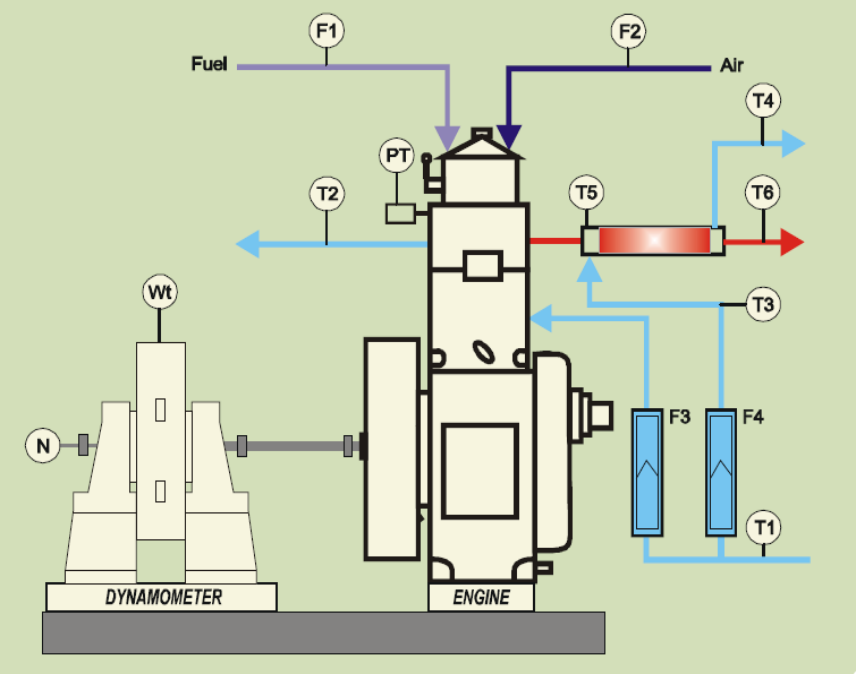

Figure 1 Shows the photograph of the experimental setup

The setup is arranged in a way to study the engine performance for brake power, indicated power, frictional power, Brake Mean Effective Pressure, Indicated Mean Effective Pressure, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio and heat balance. “Engine Soft” a Lab view

based analysis software is used to evaluate the performance of the engine. Detailed specifications as listed in Table 1.

Table 1 Experimental Setup Specifications

S.No.	Component	Specification
1	Engine	Single cylinder four stroke, Make Kirloskar
2	Power	5.2kW
3	Speed	1500 rpm
4	Stroke	110 mm
5	Bore	87.5 mm
6	Dynamometer	Eddy Current, water cooled type
7	Piston	Yttria-Stabilised Zirconia
8	Piezo Sensor range	5000PSI
9	Crank Angle Sensor Resolution	1^0, speed 5500rpm with TDC Pulse
10	Temperature Sensor Type	RTD PT100
11	Thermo Couple Type	K
12	Software	Engine Soft- Lab view based
13	Fuel	Rapeseed oil B100

Taking combustion stability as one of the important parameter, this study was conducted for single cylinder four stroke diesel engine with 100% YSZ thermal barrier coating and 100% Rapeseed oil as the fuel. The research is divided into two parts first the 100% coated piston is tested for 0-100% Rapeseed oil and then later the same coated piston with 0-100% Rapeseed oil is tested with varying EGR rates 10%, 15% and 20%.

3. RESULTS AND DISCUSSIONS

At first the Yttria-Stabilised Zirconia coated piston is tested with 100% Rapeseed oil (B100) to analyse performance and emission characteristics.

Performance Characteristics of B100 (Rapeseed Oil) in Combination of Variable EGR Rates

For different EGR rates the variation in indicated power(IP), Brake power (BP) is as show in Figure 2.

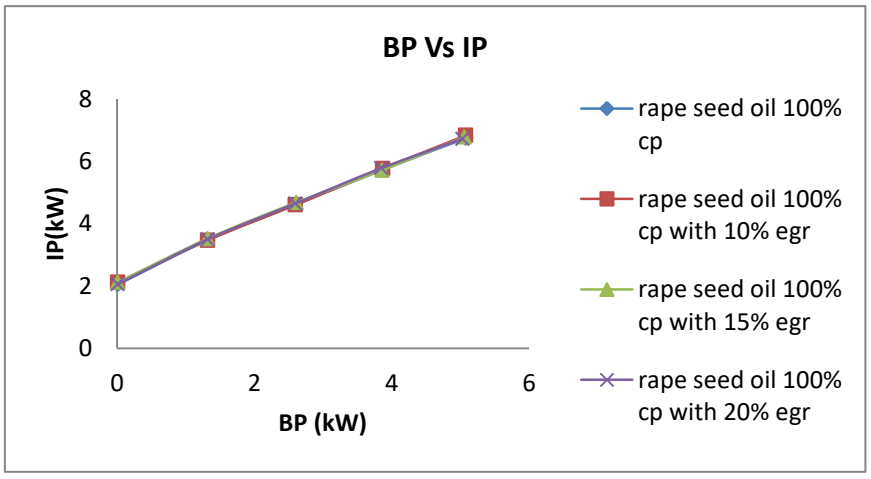

Figure 2 Variation of BP and IP for different EGR rates

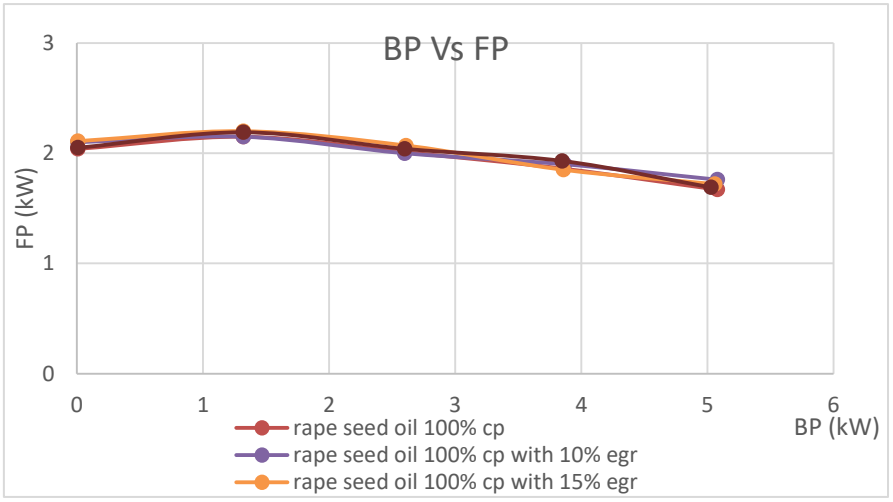

Figure 3 Variation of BP and FP for different EGR rates

The Indicated thermal efficiency of the engine is little fluctuating and attained maximum efficiency of 48.59% at a load of 4.51 kgs. The brake thermal efficiency of the engine increases as the load and speed increases and was maximum at 13.5 kgs. and the BTE was around 31.91% for Rapeseed oil without EGR. Brake Thermal Efficiency of the engine decreases with the increase in percentage rate of EGR at peak loads as shown in Figure 4.

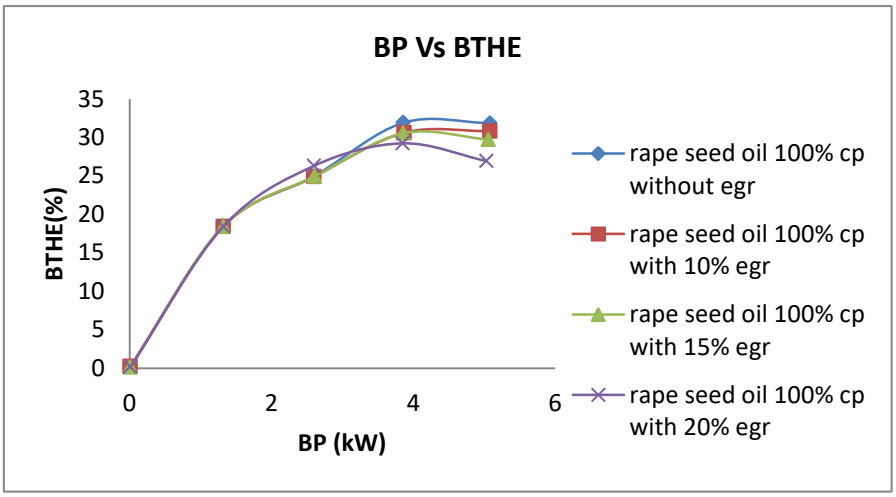

Figure 4 Variation of BP and BTHE for different EGR rates

Initially at a low loading conditions the specific fuel consumption was very high and the decrease of the specific fuel consumption was very sharp as the load and speed increases and the least SFC 0.3 kg/kWh was observed at a load of 13.5Kgs and remained constant even at peak loads as shown in Figure 5.

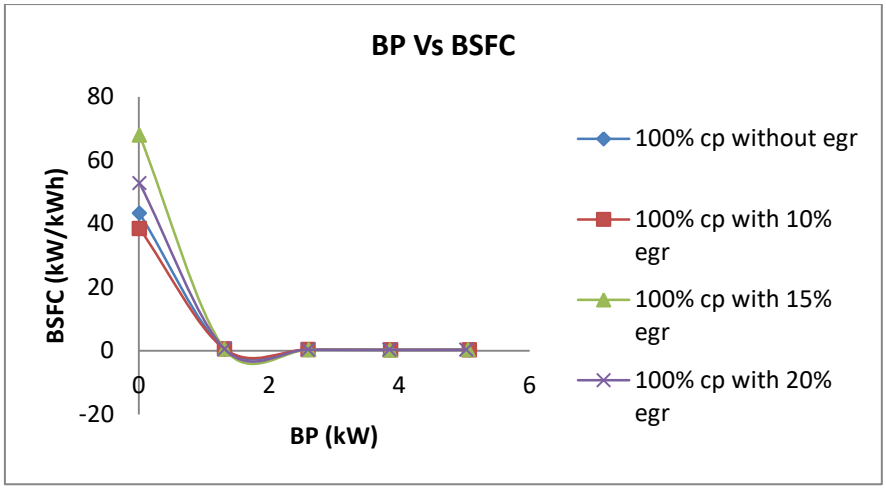

Figure 5 Variation of SFC with BP

For YSZ thermal barrier coated piston with 100% Rapeseed oil the overall performance of the engine is good at an optimum load of 13.5 kgs and 1503 rpm.

Emission Characteristics of Rapeseed oil with YSZ Thermal Barrier Coating

With the use of Rapeseed oil biodiesel there is decrease in emission of CO in comparison with diesel as fuel. The emission of CO, CO_2 and HC increases with increase in Brake Power as shown in Figure 6, Figure 7 and Figure 8 for with and without EGR. The emission of CO, CO_2 and HC is less in case of piston coated with YSZ without EGR and these emissions CO, CO_2 and HC increases with increase in rate of EGR and is maximum for YSZ coated piston with Rapeseed oil fuel with 20% rate in EGR. Whereas the functionality of the EGR is sustained in emission of NOx i.e. the emission of NOx is maximum in case of YSZ coated piston without EGR and is least in case of maximum rate of EGR as shown in Figure 9.

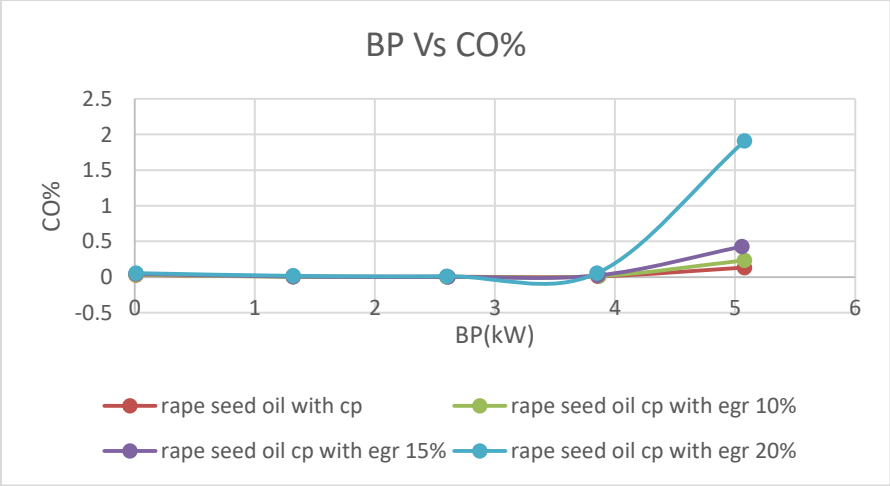

Figure 6 Emission rates of CO without and with 10%, 15% and 20% EGR

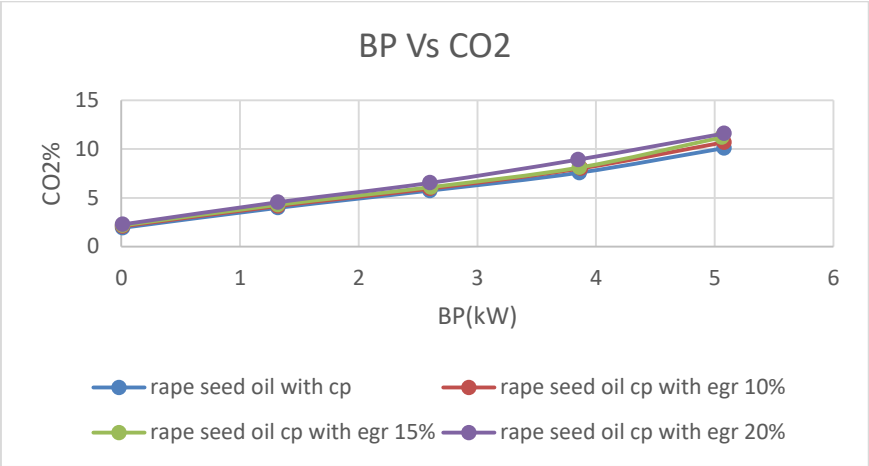

Figure 7 Emission rates of CO_2 without and with 10%, 15% and 20% EGR

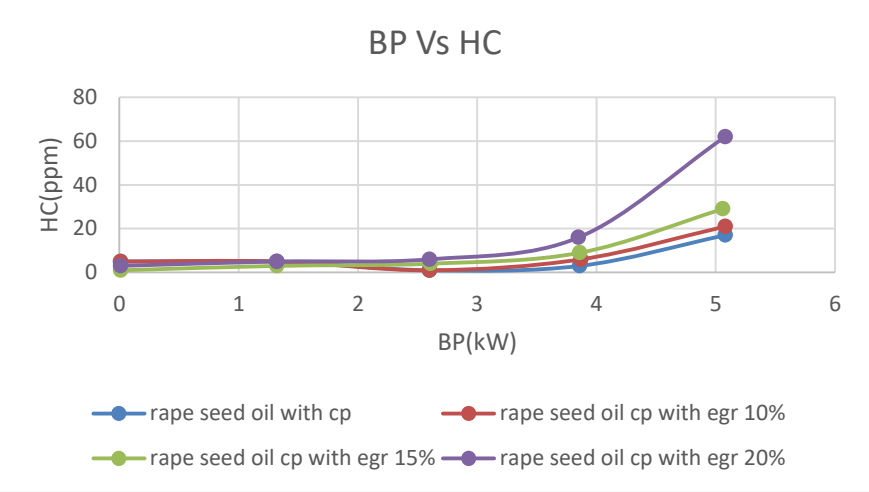

Figure 8 Emission rates of HC without and with 10%, 15% and 20% EGR

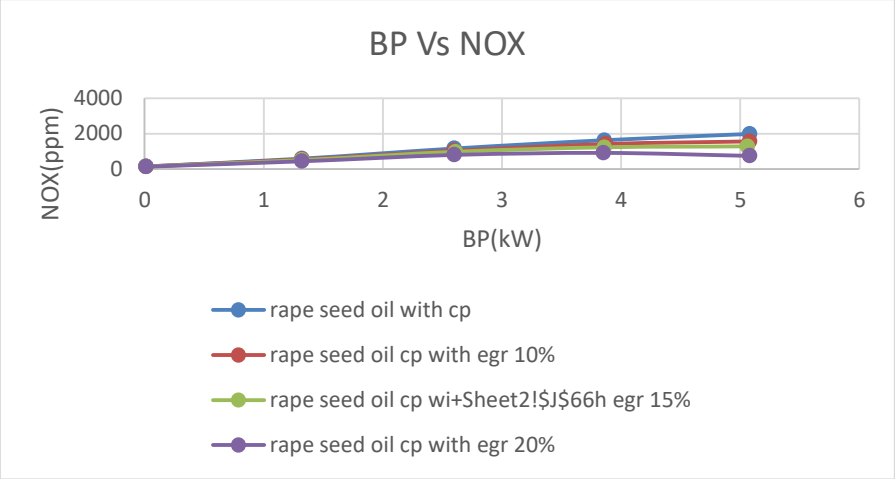

Figure 9 Emission rates of NOx without and with 10%, 15% and 20% EGR

4. CONCLUSIONS

The following conclusions are drawn in case of YSZ coated piston with Rapeseed biodiesel B100 as fuel with and without usage of EGR.

- The performance of the engine is good without use of EGR but the variation is very little when different EGR rates are used at the peak loads, this is because of increase in frictional power loss.
- By using B100 as fuel and YSZ coated piston without EGR the emission of CO, CO2 and HC decreases at peak loads but NOx emission increases
- On the other hand, with varying rates of EGR i.e. 10%, 15% and 20% EGR the NOx emissions decreases. With increasing rates of EGR NOx emission decreases

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