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PERFORMANCE USING SOYABEAN OIL WITH THERMAL BARRIER COATING FOR PISTON CROWN IN DIESEL ENGINE

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ABSTRACT

As per the second law of thermodynamics the efficiency of the engine depends upon the extraction of work against the heat supplied. Minimization of heat rejection leads to increase the work. Heat rejection takes place through the engine piston, valves and cylinder heads to the surroundings. Heat transfer through the engine parts is minimized by applying the thermal barrier coating materials on the top surface of the engine piston, cylinder heads and valves.

On the other hand, the improvements in engine materials are forced by using alternative fuels and environmental requirements. Therefore, the performances of engine materials become increasingly important. For improving the performance of engine, thermal barrier coatings (TBCs) are a promising step forward. In this experimental study, Yittria Stabilised Zirconia is used as the thermal barrier coating. The purpose of using this material is to reduce the heat loss from engine. TBCs are done by atmospheric plasma spraying technique. Engine working conditions are maintained constant before and after coating. Blends are made by using Transverification process.

Further in the second step experimental investigations were carried out on the same engine with same operating parameters by using Soybean Oil and its blends with diesel in different proportions such as 10%, 20%, 30%, 40%, 50% of Soybean Oil with diesel fuel to find out the performance parameters and emissions. It was observed that there are less CO, HC, NO and CO2 emissions compared to diesel.

KEYWORDS*: Diesel Engine, Soybean Oil, TBC, YSZ, plasma spray technique Performance and emissions characteristics*

I. INTRODUCTION

Energy conservation and efficiency have always been the quest of engineers concerned with internal combustion engines. Even the diesel engine rejects about two thirds of the heat energy of the fuel, one-third to the coolant, and one third to the exhaust, leaving only about one-third as useful power output. Theoretically if the heat rejected could be reduced, then the thermal efficiency would be improved. Low Heat Rejection engines aim to do this, by reducing the heat lost to the coolant. The rapid increase in fuel expenses, the decreasing supply of high grade fuels on the market and environment concerns stimulated research on alternate fuels and more efficient engines with acceptable emission characteristics. The state of art thermal barrier coating (TBC) provides the potential for higher thermal efficiencies of the engine. In addition ceramic shows better wear characteristics than conventional material. Ceramics have a higher thermal durability than metals. Therefore it is usually not necessary to cool them as fast as metals. Lower heat rejection from the combustion chamber through thermally insulated components causes an increase in available energy that would increase the in-cylinder work and the amount of energy carried by exhaust gases, which could also be utilized. Using the coated piston the required temperature in the combustion chamber will be maintained. This will reduce the heat loss to the piston. This reduction in the heat loss will be used to burn the unburnt gases there by reducing the polluted exhaust gases.

II. LITERATURE REVIEW

X.Q. Cao et al. (2004) [1], has done an experimental investigation on Ceramic Materials for Thermal - Barrier Coatings. The main objective of this paper is to study about ceramic materials. Ceramics, in contrast to metals, are often more resistance to oxidation, corrosion and wear, as well as being better thermal insulators. Except yttrium stabilized zirconium, other materials such as lanthanum zirconate and rare-earth oxides are also promising materials for thermal barrier coatings.

I. Tymaz et al. (2005) [2] has done an experimental investigation on Experimental Study of Effective Efficiency in a Ceramic Coated Diesel Engine. The combustion chamber surfaces (cylinder head, valves and piston crown faces were coated with ceramic materials. Ceramic layers were made of CaZrO3 and MgZrO3, by using plasma-coating method onto the base of the NiCrAl bond coat. The ceramic-coated research engine was tested at the same conditions as the standard (without coating) engine. The results showed a reduction in heat loss to the coolant and an increase in effective efficiency.

Ekrem BuyuKKaya et al. (2007) [3], has done an analysis on Effects of Thermal Barrier Coating on Gas Emissions and Performance of a LHR Engine with Different Injection Timings and Valve Adjustments. The study of this paper, it is find that firstly thermal analyses are investigated on a conventional (uncoated) diesel piston, made of aluminium silicon alloy and steel. Secondly, thermal analyses are performed on pistons, coated with MgO–ZrO2 material by means of using a commercial code, namely ANSYS. Finally, the results of four different pistons are compared with each other. The effects of coatings on the thermal behaviour of the pistons are investigated. It has been shown that the maximum surface temperature of the coated piston with material which has low thermal conductivity is improved approximately 48% for the AlSi alloy and 35% for the steel.

Aravinth et al. (2012) [4], has done an experimental investigation on Comparison of Various Thermal Barrier Coatings along with their Effects on Efficiencies and Fuel Consumption based on the Results of Experimental Literatures. It is well known fact that about 30% of the energy supplied is lost through the coolant and the 30% is wasted through friction and other losses, thus leaving only 30% of energy utilization ion for useful purposes. There have been numerous research papers in recent years describing the theoretical benefits obtained from the use of ceramic components in reciprocating engines, but that describes practical results is very limited. Thermal Barrier Coatings (TBC) in internal combustion engine have advantages such as improved thermal efficiency and combustion, reduction in weight by eliminating cooling systems, etc. however, practical problems are faced in implementing these coatings in internal combustion engines. The problem presently faced in implementing of TBC as engine cylinder is thermal mismatch which mainly occurs due to improper adhesion and difference in thermal expansion coefficient between bond coat and cylinder materials. TBC must also withstand wear an d tear. The disadvantage of the TBC method is that NO_X emission is increased.

R.J et al. (2005) [5], has done an experimental investigation on a Compression Ignition Engine using Bio-Diesels. The Sunflower oil and Maize oil, in view of its availability and combustion properties were shown in this investigation. Use of Sunflower and maize methyl esters is found to be very effective method of eliminating almost all the undesirable combustion features of vegetable oils. Sunflower oil Methyl Esters (SME); Maize oil Methyl Esters (MME) were prepared, which showed low viscosity, heat content, and density close to that of diesel oil. Esterification brings about a modification in the molecular structure of the Sunflower oil and Maize oil, thus converting it into Bio-Diesel, a fuel for utilization in the diesel engines.

III. THERMAL BARRIER COATING

Thermal barrier coatings can be applied in the IC engine to insulate combustion chamber surfaces. The coatings can be applied to the entire combustion chamber or to select surfaces like the piston crown or valves. The primary purpose of the TBC is to raise surface temperatures during the expansion stroke, thereby decreasing the temperature difference between the wall and the gas to reduce heat transfer. Some of the additional heat energy in the cylinder can be converted into useful work, increasing power and efficiency. Reducing heat transfer also increases exhaust gas temperatures, providing greater potential for energy recovery with a turbocharger. Additional benefits include protection of metal combustion chamber components from thermal stresses and reduced cooling requirements. A simpler cooling system would reduce the weight and cost of the engine while improving reliability. Thermal barrier coatings are most commonly stabilized Zirconia such as Yttria Stabilized Zirconia (YSZ), but other ceramics like Silicon Nitride (SN) have been used. Thermal conductivities (k) have ranged from less than 0.5 W/mÀK to 10 W/mÀK and thicknesses have ranged from 0.1 mm to 4.5 mm. Ceramic coatings can be applied by a variety of methods.

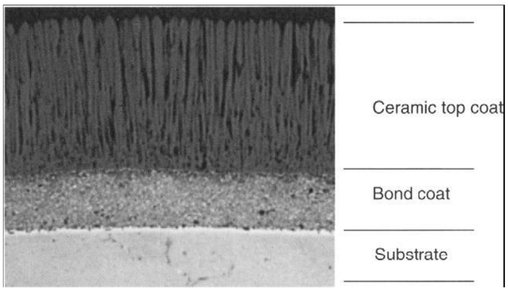


Figure 1 TBC consist of TC and BC

IV. METHODS OF SPRAYING TBC IN IC ENGINES

1. Plasma Spray (SP)
2. Chemical Vapour Decomposition
3. Ion Coating
4. Splash Coating
5. Electron Beam Evaporation Coating
6. Flame Spray
7. Sol-gel (SG)
8. Detonation Gum (DG)
9. Reactive ion coating

V. PLASMA SPRAY TECHNIQUE

The main objective in plasma spraying was to constitute a thin layer that has high protection value over other exposed surfaces. Ni-Cr is sprayed in powder form molten in ionized gas rapidly on the piston crown surface to form a 100 micron thin TBC coating. A typical Plasma spray coating system is shown in Figure. The system primarily consists of power unit, powder supply unit, gas supply unit, cooling system, spraying gun and control unit. The coating material is Nickel-Chromium and Ceramic. The plasma generator consists of a circular anode, usually of copper, and a cathode of tungsten. The cathode is made of graphite in a water stabilized torch. A strong electric arc is generated between anode and cathode. This ionizes the flowing process gasses into the plasma state. Now, powdered feedstock material is injected into the plasma jet. Plasma jet will melt the material and propel it onto the work piece surface. Atmospheric plasma spraying is carried out using a Sulzer Metro F4 gun operating at power levels up to 50 kW. A gas mixture of hydrogen and argon is used as a plasma gas. The argon gas is also considered as a carrier gas for the feedstock material injection.

VI. PROPERTIES OF THERMAL BARRIER CERAMIC MATERIALS

1. High chemical stability.
2 Resistant to high temperatures.
3. High hardness values.
4. Low densities.
5. Can be found as raw material form in environment.
6. Resistant to wear.
7. Low heat conduction coefficient.
8. High compression strength.

VII. ALTERNATE FUELS

The bio-fuels such as alcohols and biodiesel have been proposed as alternatives to Internal Combustion Engine diesel fuel because of their biodegradability and non toxicity. These fuels have received wide attention because They significantly reduce exhaust emissions and the overall life cycle emissions of carbon dioxide (CO2) when they burnt as fuel. In 1973 OPEC (Organization of Petrol Exporting Countries, founded in 1960) put an embargo on oil production and started an oil pricing control strategy. Oil prices shot up four folds causing severe energy crisis the world over. This resulted in spiraling price rise of various commercial energy sources leading to global inflation.
So, the search for alternative renewable fuels is required. Most suitable alternative kinds of fuel for diesel engines may be considered vegetable oil or fuel obtained from the animal fat, because their characteristics are similar to those of common diesel oil. There are number of plants producing oils which can be used in internal combustion engines. Soybean oil is a vegetable oil extracted from the seeds of the soya bean. It is one of the most widely consumed cooking oils. As a drying oil, processed soybean oil is also used as a base for printing inks (soy ink) and oil paints.

VIII. EXPERIMENTAL SETUP

Here a four stroke diesel engine connected with electrical loading is used to estimate the performance analysis at different loading conditions and diesel blend with piston coating and without piston coating.

Table 1 Specification of Diesel Engine

<table>
<tr><td colspan="2">Bore</td><td colspan="2">80mm</td></tr>
<tr><td colspan="2">Stroke</td><td colspan="2">110mm</td></tr>
<tr><td colspan="2">RPM</td><td colspan="2">1500</td></tr>
<tr><td colspan="2">BHP</td><td colspan="2">5</td></tr>
<tr><td>CR</td><td>Generator efficiency</td><td>16:1</td><td>80%</td></tr>
</table>

Figure 2: Four stroke single cylinder diesel engine set up with generator loading

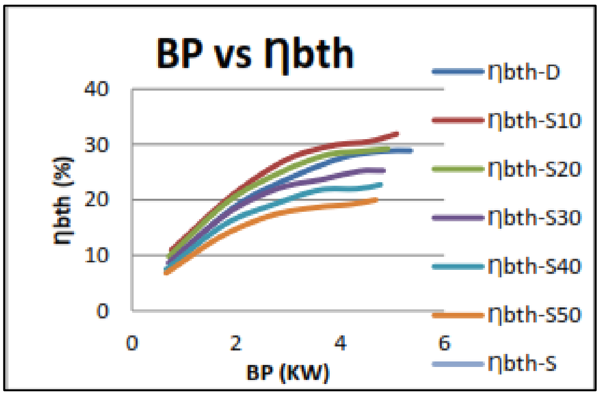
This experimental setup consists of four-stroke diesel engine connected with electrical loading. By using this experimental setup estimating the performance and emission analysis at different loading conditions and different diesel blends, with piston coating, and without piston coating. The engine specifications are CR : 16:1 Maximum current : 13 amp Generator efficiency: 80 %

IX. EXPERIMENTAL PROCEDURE

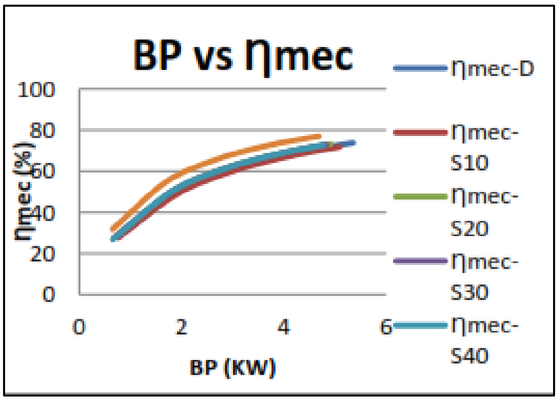
Initially the engine is running with diesel fuel for the duration of 10 to 15 minutes before using camphor oil blends in order to attain stable working environment. After that diesel fuel is completely drained out from the fuel tank and then the sample of (500 ml) camphor oil-diesel blends are poured into the fuel tank. It is important to note that whether the engine has attained its optimum (warm) temperature conditions. At constant speed of 1500 rpm, engine is loaded with 0%, 5%,25%, 50%, 75%, 100% load by using an eddy current dynamometer. The B15 & B20 proportions of camphor oil blends are tested at all load conditions running at constant speed, where the experimental procedure is same for every proportion to be tested.

X. PERFORMANCE OF DIESEL BLENDS WITHOUT PISTON COATING

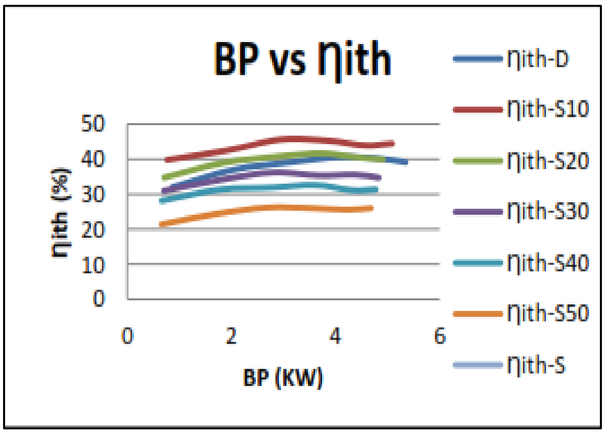
10.1 At fuel injection pressure 180bar



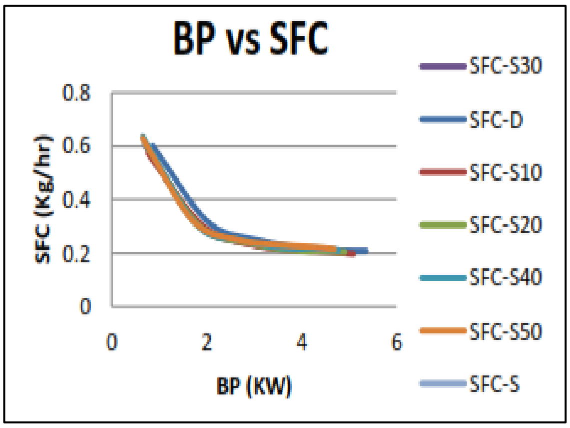
Graph 3.1.1 Performance of diesel blends at 180 bar Pressure BP VS ηbth



Graph 3.1.3 Performance of diesel blends at 180 bar pressure BP VS ηmec

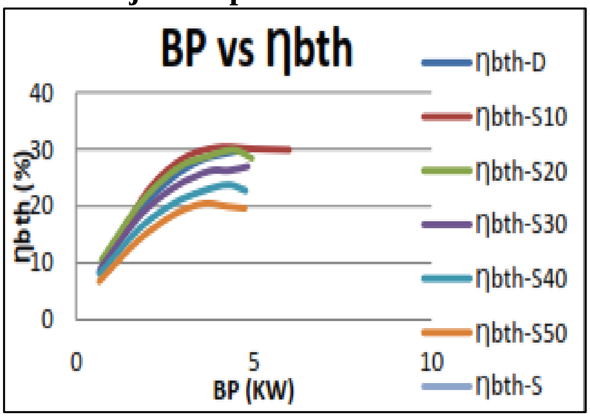


Graph 3.1.2 Performance of diesel blends at 180 bar pressure BP VS ηith



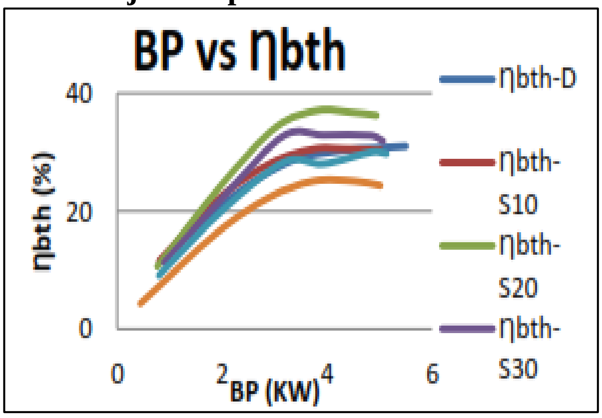
Graph 3.1 4 Performance of diesel blends at 180 bar pressure BP VS SFC

10.2 Diesel blends piston coating At fuel injection pressure 180 bar

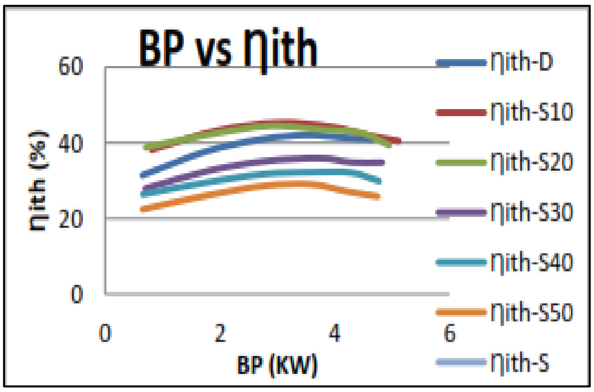


Graph 3.2.1 performance of diesel blends at 180 bar pressure BP VS ηbth

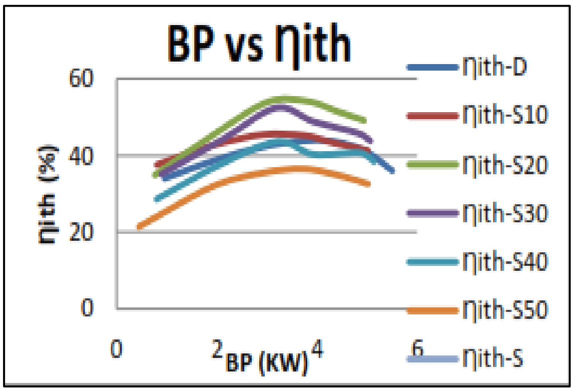
10.3.Diesel blends without piston coating At fuel injection pressure 205 bar



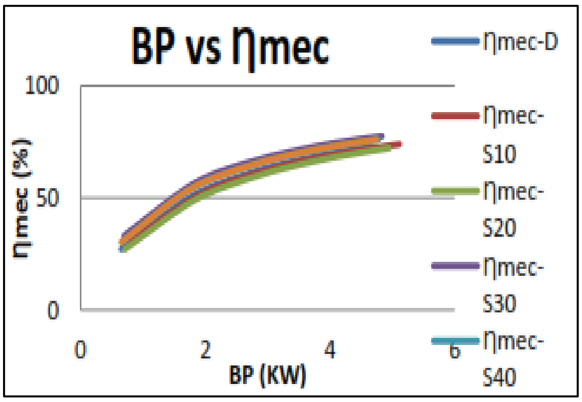
Graph 3.3.1 Performance of diesel blends at 205 bar pressure BP VS ηbth



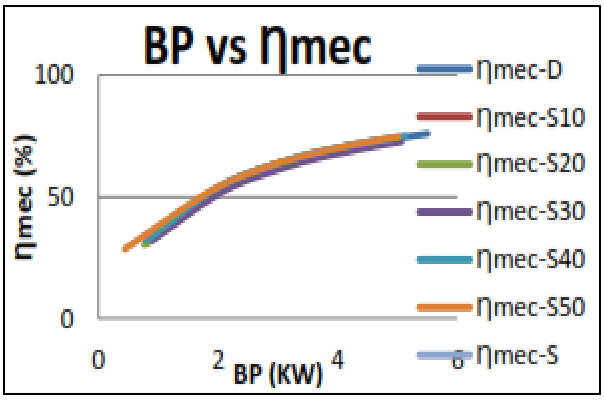
Graph 3.2.2 Performances of diesel blends at 180 bar pressure BP VS ηith



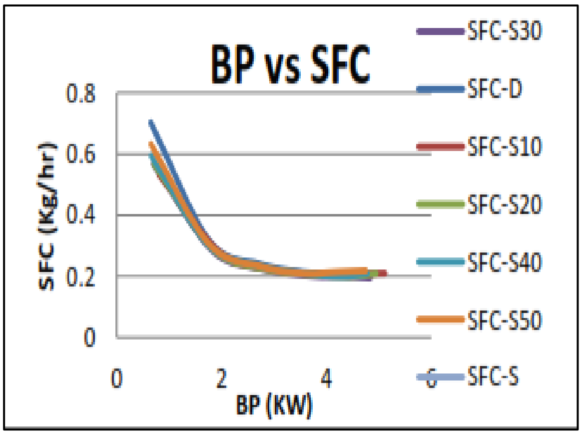
Graph.3.3.2 Performance of diesel blends at 205 bar pressure BP VS ηith



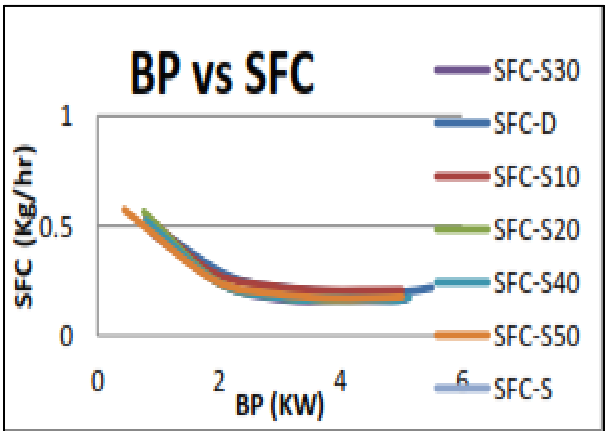
Graph 3.2.3 Performances of diesel blends at 180 bar pressure BP VS ηmec



Graph 3.3.3 Performance of diesel blends at 205 bar pressure BP VS ηith



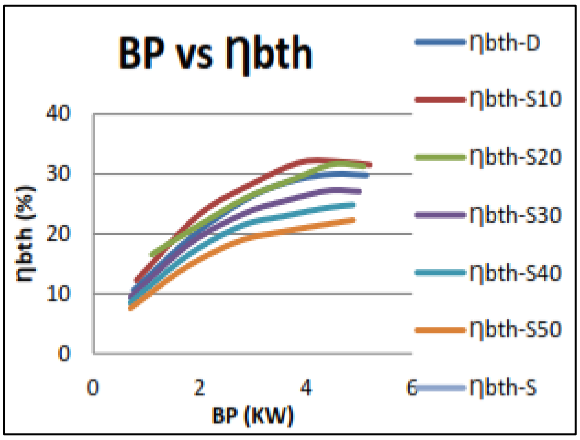
Graph 3.2.4 Performance of diesel blends at 180bar Pressur BP VS SFC



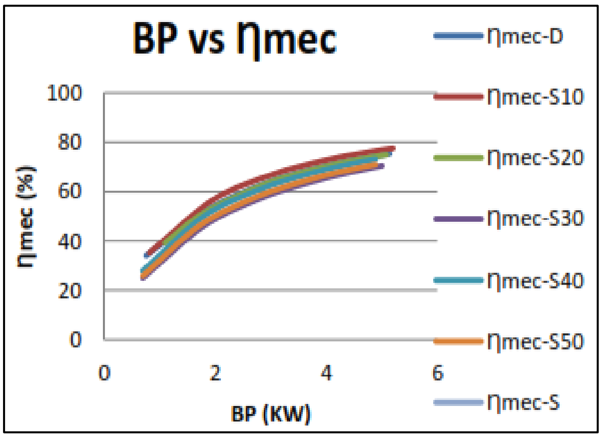
Graph 3.3.4 Performance of diesel blends at 205 bar Pressure BP VS SFC

10.4 Diesel blends piston coating

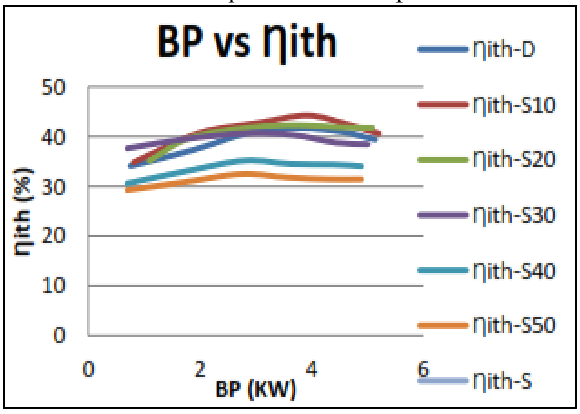
At fuel injection pressure 205 bar



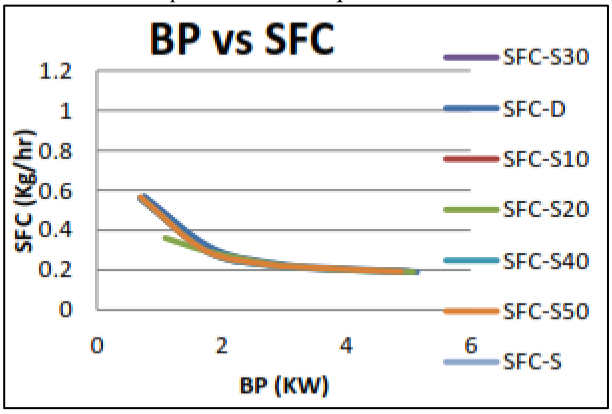
Graph 3.4.1 Performance of diesel blend at 205 bar pressure BP VS Ƞbth



Graph 3.4.3 Performance of diesel blends at 205 bar pressure BP VS Ƞmec



Graph 3.4.2 Performance of diesel blends at 205 bar pressure BP VS Ƞith



Graph 3.4.4 Performance of diesel blends at 205 bar Pressure BP VS SFC

XI. RESULT

By using Yittria Stabilised Zirconia as piston coating and fuel as soya bean oil the efficiencies such as mechanical, brake thermal efficiency, indicated thermal efficiency and volumetric efficiency can be increased. Special fuel consumption reduces.

XII. CONCLUSION

As like many alternative fuels soya bean oil also used as bio diesel in diesel engines because of its desirable properties. Many projects have done by coating the piston crown with different chemicals. In this work the coating is made with Yittria Stabilised Zirconia. By this the efficiencies of the system can be increased which are merely similar to other.

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