EFFECT OF ZIRCONIUM COATED PISTON ON PERFORMANCE OF A DIESEL ENGINE FUELED WITH METHYL ESTER OF PEANUT OIL

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Abstract — ***In the present study, experiments have been conducted on four stroke, single cylinder, water-cooled, diesel engine whose piston crown is coated with thermal barrier coating material formed from yttria stabilized zirconia (YSZ). Biodiesel has been obtained from peanut oil through tranesterification. Sequences of experiments are performed on the engine with thermal barrier coating by supplying diesel, biodiesel and B50 (biodiesel blend) as feedstock. Performance and emission characteristics obtained from the experiment is used to line the network with the load and fuel type being the input parameter and the brake specific fuel consumption, brake thermal efficiency, CO, HC, NOx, CO2 emissions being the output parameter .Results showed that the low heat rejection (LHR) engine fuelled with 100% biodiesel land biodiesel blend (B50) resulted in reduced emissions compared with diesel.***

Keywords — *Diesel engine, Low heat rejection engine, Thermal barrier coating, yttria stabilized zirconia, peanut methyl ester.*

I. INTRODUCTION

Energy obtained from renewable and alternative fuels is a fundamental input for economic growth of any country. It is quite necessary in the present world's energy scenario to use alternative fuels because of their energy security, environmental concerns, foreign exchange savings and socioeconomic issues[1] .It was identified even at the early years of development of internal combustion engines that the alternate fuels are going to play an vital role in the future to meet the expanded energy consumption and to reduce tail pipe emissions, which stimulate Dr.Rudolph Diesel to use vegetable oil as fuel in his designs. Direct use of vegetable oils and / or the use of blends of the oils have roughly been considered to be impractical and not convincing for both direct and indirect diesel engines. The high viscosity, acid composition, free fatty acid content, as well as gum formation as a result of oxidation, carbon deposits and lubricating oil thickening are obvious problems [2]. A set of methods are available for modifying vegetable oils to make them suitable for use in the engines The most significant being transesterification. A chemical process called transesterification in which glycerine is separated from the fat or vegetable oil is used to extract biodiesel. At the end of chemical process couple of product is left behind: methyl esters (the chemical name for biodiesel) and glycerine (a valuable by product normally sold to be used in soaps and other products).

Methods of obtaining maximum energy out of biodiesel fuel in diesel engines are ongoing and Low Heat Rejection Engine (LHR) is one of the areas of interest in the engine development association since the recent past. The combustion chamber temperature is high in the low heat rejection engines (LHR) in which some or all parts of the combustion chamber are coated with a ceramic material, biodiesel can be used more efficiently in these engines .To establish suitable conditions for the thermodynamics cycle in the internal combustion engine, it is necessary to create the elements of the combustion chamber from materials of low thermal conductivity. One of the available methods to adiabatize an engine is to envelope the surface of the combustion chamber with thermal barrier coatings (TBC). The thermal insulation thus obtained is supposed to lead, according to the second law of thermodynamics, to an enhancement in the engine's heat efficiency and a reduction in consumption. Higher temperatures in the combustion chamber can also have a positive effect in diesel engine.

TABLE I
TEST ENGINE SPECIFICATIONS

TYPE	SPECIFICATION
Type of engine	Kirloskar model tv1
Stroke	4
Number of cylinders	1
BORE/ STROKE (mm)	87.5/110
Compression ratio	17:5:1
Maximum engine power (kw)	5.2 (1500 rpm)
Fuel type	Diesel
Lubricating	Full pressure
Type of injection	Direct injection
Type of coolant	Water coolant
Maximum Engine Speed (1/min)	1500
Engine Volume (mm^3)	2000 x 2500 x 1500

Very limited percentage of total energy supplied to the engine is converted into useful energy in the internal combustion engines. In order to save energy, it is an advantage to prevent the hot parts by a thermally insulating layer. This will diminish the heat transfer through the engine walls and a greater percentage of the energy produced can be utilized, involving an increased efficiency. The changes in the combustion process due to insulation also affect exhaust emissions [3]. Coating engines with ceramic materials partly or entirely has been initiated to be used recently. The aim of the studies on this matter is generally to enhance the engine's performance, to make the parts extra resistant against wear. For this purpose, both engine parts are coated by using various methods. Various methods are used in TBC. Thermal barrier coatings are generally practiced on cylinder head, piston and valves through plasma spray method.

Plasma spray method is one of the high technologies for coating technique. Ceramic based composites used in this plasma spray process, are produced by a high wear resistant and thermal barrier effect on the material surface because of their physical and chemical properties [4, 5].

In this test case, the piston crown alone is coated with ceramic, our study performed using methyl ester, blends of biodiesel fuel and diesel fuel is expected to contribute to this area. This study reviews effects of using of peanut oil methyl ester, B50 (50% biodiesel, 50% diesel) and diesel fuel in a diesel engine whose piston crown was coated yttria-stabilized zirconia (YSZ). Methyl ester was obtained from raw peanut oil through transesterification method. The test fuels where used in diesel engine under full-load and distinct speed conditions to compare the results of distinct fuel.

II. EXPERIMENTAL

Experiments were conducted on the single cylinder, four-stroke, direct injection, water-cooled diesel engine. All laboratory tests employed on electrical dynamometer as shown in Fig 1. Technical parameters of the engine are given in Table I. The gas analyser specification is given in the Table II.

TABLE II
GAS ANALYZER SPECIFICATION

Measurement data	Resolution
Co-0 to 15% Vol	0.0001% Vol
HC-0 to 2000 ppm Vol	1ppm/10ppm
Co_2-0 to 20% Vol	0.1% Vol
O_2-0 to 25% Vol	0.01% Vol
NO_x-0 to 6000 ppm Vol	1 ppm Vol

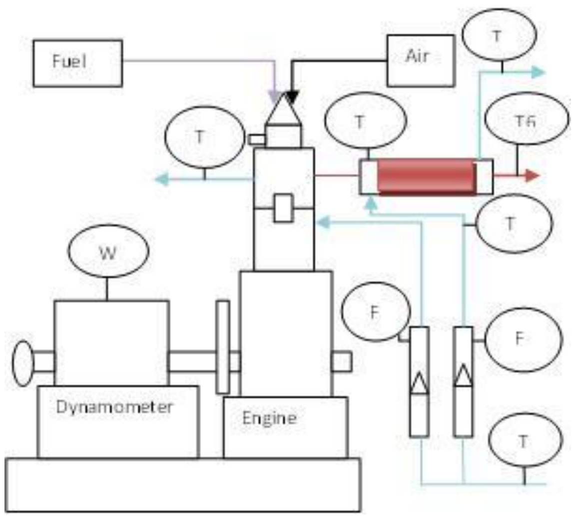

Fig 1: Schematic of test set-up.

In this test case, methyl ester made of raw peanut oil and B50 (50% methyl ester, 50% diesel) were used as alternative feedstock. 100% pure diesel fuel was also used as reference for making comparison. Methyl ester was obtained from raw peanut oil by transesterification. The pictorial representation of methyl ester Manufacturing is noticed on Fig 2.

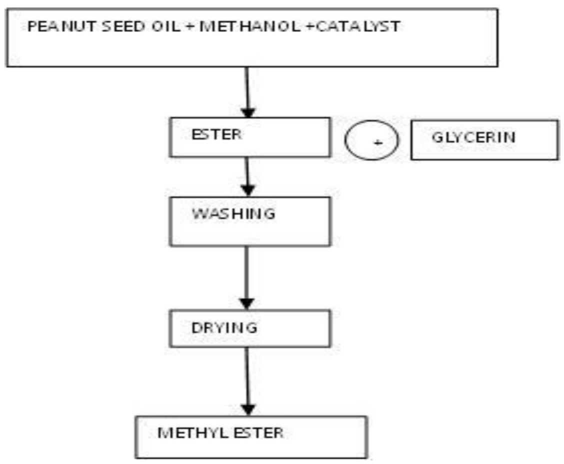

Fig 2: Flow chart of peanut methyl ester manufacturing.

A. Production Procedure For Biodiesel

Biodiesel derived from peanut seed oil was prepared by reacting 900 g of oil, 180 g CH3OH (approximately 6:1 molar ratio) and 4.5 g KOH. The reaction was carried out for 1.5 h under reflux at 60°C stirring. The reaction was carried out using 100% excess methanol, (i.e. molar ratio of methanol to oil is 6:1) and catalyst concentration of 0.5%. The reaction mixture was then allowed to settle overnight and the methyl ester layer was separated from the glycerol layer with the help of separatory funnel. After completion of reaction, crude glycerol was allowed to separate by gravity. The catalyst (KOH) was get rid off by hot water washings. With the help of Phenolphthalein indicator the complete removal of catalyst was checked. Traces of moisture and untreated methanol were removed by vacuum distillation. The distillation was continued until the loss in weight of ester was constant thus confirming the complete removal of moisture and untreated methanol. The crude methyl ester was further purified by distilling off the untreated methanol under normal atmospheric pressure, washing several times with water, centrifugation and drying with vacuum desiccators. The reaction mixtures were allowed to cool down to room temperature to produce two phases: crude ester phase and glycerol phase, after the completion of transesterification.

This phase separation normally occurred shortly and can be noticed within the first 10-15 min of settling, but the ester layer was cloudy, indicating that the separation was partial. An experimental result provides that given enough time for complete settling, the opaque ester phase could turn crystalline and transparent. This complete separation could take as long as 8–20 h. In fact, during the settling, the transesterification process was still going on. Therefore, the longer the settling time, the more favourable are the separation and the conversion. All chemicals used were of analytical grade unless otherwise stated. The physical and chemical properties of the test fuels are provided in Table III. From table, a sharp decrease in the viscosity of the vegetable oil is observed due to transesterification method. Piston crown was coated with ysz, which is a ceramic material, to a thickness of 100µm by plasma spray method. Coatings were using an atmospheric plasma-spray system, type 3MB.spray parameters are given in Table IV.

TABLE III

THE PHYSICAL AND CHEMICAL PROPERTIES OF FUELS

PROPERTIES OF FUEL	DIESEL	B50	B100
DENSITY	840	874	910
VISCOSITY AT 40° (mm2/s)	4.65	4.07	4.8
FLASH POINT(°C)	35	57	166.0
CALORIFIC VALUE (KJ/Kg)	42500	38,487	36,154

III. **TABLE IV**

SPRAY PARAMETERS APPLIED IN THE COATING PROCESS

PLASMA GUN	3 MB
CURRENT (Ampere)	500
VOLTAGE (Volt)	60-70
SPRAY DISTANCE (mm)	50-76
GAS PRESSURE (Psi) (Ar/H_2)	100-120/ 50

FLOW RATE (SCFH) (Ar/H_2)	90/18
APPLIED COATING THICKNESS (µm)	100
COATING MATERIAL	YSZ

The material (chipping) has been removed in proportion to the thickness of the coating applied to obtain the standard compression. Thus the engine which is coated and the engine which is not coated have been formatted to the same compression ratio. The tests were carried at distinct engine speed. TableV shows the experimental set up notations.

IV. TABLE V
EXPERIMENTAL SETUP NOTATIONS

N	Rotary encoder
Wt	Weight
F1	Fuel flow
F2	Air flow
F3	Jacket water flow
F4	Calorimeter water flow
T1	Jacket water inlet temperature
T2	Jacket water outlet temperature
T3	Calorimeter water inlet temperature = T1
T4	Calorimeter water outlet temperature
T5	Exhaust gas to calorimeter temperature
T6	Exhaust gas from calorimeter temperature

III RESULTS AND DISSCUSSION

Figure 3 shows the brake thermal efficiency for diesel, biodiesel and its blend (B50) with respect to brake power for low heat rejection engine. The maximum efficiency obtained in the case of low heat rejection with biodiesel blend (B50) as feedstock at full load was lower than low heat rejection engine fueled diesel as input and also lower than low heat rejection engine with biodiesel as feedstock

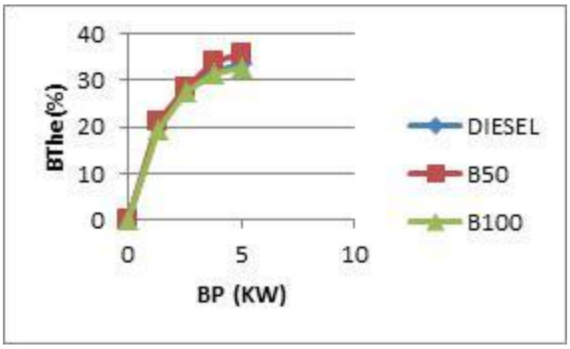

Fig 3: Variation of brake thermal efficiency with brake power.

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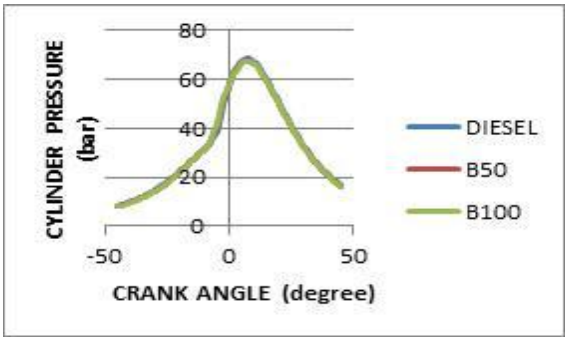

Fig 4: Variation of crank angle with cylinder pressure.

In a CI engine the cylinder pressure is depends on the fuel burning rate during the premixed burning phase, which in turn leads better combustion and heat release. Figure 4 shows that typical variation of cylinder pressure with respect to crank angle. The cylinder pressure in the case of biodiesel fueled LHR engine is lesser than the diesel fueled LHR engine and also lesser than LHR engine fueled with biodiesel blend (B50). This reduction in the cylinder pressure may be due to lower calorific value and slower combustion rates associated with biodiesel fueled LHR engine.

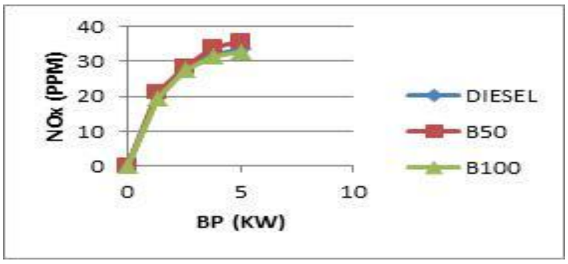

Fig 5 : Variation of NO_X with brake power.

The most vital factors in determining the NO_X emissions produced by the combustion process are stoichiometry and temperature. Figure shows the variation of NO_x with brake power. The NO_x Emission in the case of biodiesel fueled LHR engine is lesser than the diesel fueled LHR engine and also lesser than LHR fueled with biodiesel blend (B50).

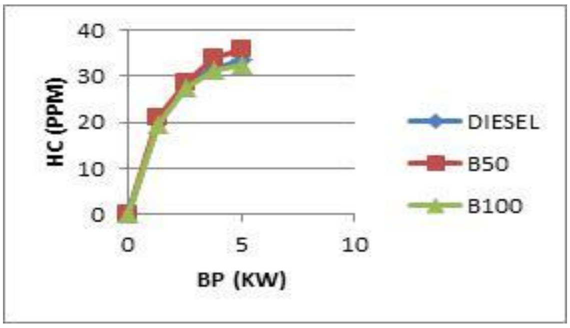

Fig 6: Variation of hydrocarbon emission with brake power.

Figure 6 displays the variation of hydrocarbon emission with brake power. The hydrocarbon emission in case of biodiesel fueled LHR engine is lesser than LHR engine which has a feedstock Diesel and also lesser than LHR engine fueled with biodiesel blend (B50).

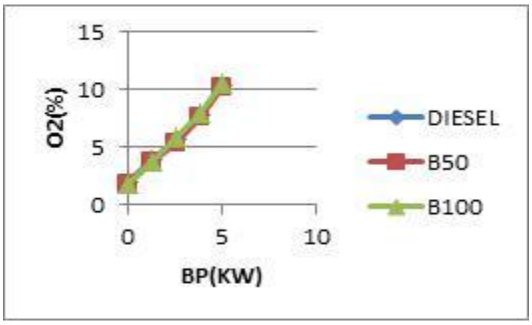

Fig 7: Variation of o_2 emission with brake poewr.

Figure7displays the variation of o_2 with brake power.The o_2 emission in case of LHR engine with biodisel as feedstock is higher than LHR engine with diesel as input and also higher than LHR engine with biodiesl blend (B50) as feedstock.

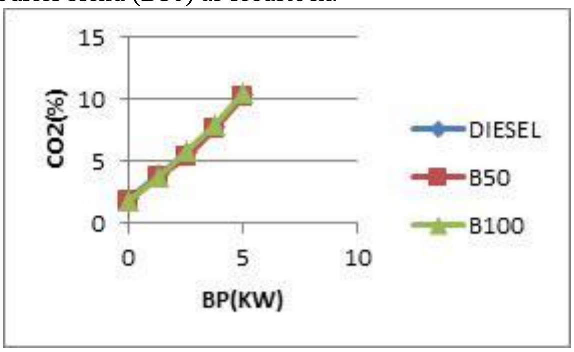

Fig 8: Variation of co_2 emission with brake power.

Figure 8 display the variation of co_2 with brake power. The carbon dioxide emission in case of LHR engine with biodiesel as feedstock is higher than LHR engine with input as diesel and also higher than LHR engine with biodiesel as feedstock.

V. CONCLUSION

In this experimental study, the peanut oil methyl ester and its blend B50 (50% methyl ester, 50% diesel) were used as alternative feedstock in low heat rejection diesel engine and compared with low heat rejection engine fuelled with diesel. As a result of this test:

1. NOx emission with biodiesel fuel showed lesser value compared with diesel fuel and biodiesel blend (B50).
2. Biodiesel fuel showed less HC emission than those of diesel and biodiesel blend (B50)
3. Biodiesel blend (B50) provides high brake thermal efficiency value compared to diesel fuel and biodiesel fuel.

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