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Performance and Emission characteristics of Diesel-Rice bran biodiesel blend ratios using different piston dimensions in Diesel engine

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Abstract : The present investigation focuses on analyzing the evaluation characteristics of rice bran biodiesel (RBBD) in Diesel engine (KIRLOSKAR DM10) experimentally. The compression ratio of the Kirloskar engine is modified by changing the shapes of the piston compared to Hemispherical existing piston (HEP). The variable piston dimensions of the engine were differentiated by attrition and metal deposition to form Toroidal piston (TP) and Deep Toroidal Re-entrant piston (DTRP).The effects of engine investigation are studied using the blend proportions of RBBD with existing and modified piston dimensions. The engine performance characteristics show an increase in brake thermal efficiency (BTE) with brake power (BP) and marginal increasing specific fuel consumption. The emission characteristics of the CO and HC are originated to be decrease with TP where as DTRP demonstrates pessimistic perfection. The oxides of nitrogen emission are formed to increase with DTRP.
Keywords : Compression ratio, brake thermal efficiency, oxides of nitrogen, piston dimensions.

Introduction

The internal combustion (IC) engine has a one of the best part in our life. It plays a main role in the field of industrial, transportation and agricultural divisions. The compression ignition engine is more suitable mode of transportation for provide the higher efficiency compared to petrol engine. Compression ignition engine is used in the various sectors and it is provide the lots of investigators to analyse the engine characteristics. Engine investigations leads to improve the performance and minimum emissions particles. The fuel injection timings, cylinder air motion, combustion pressure range and piston crown measurements are important parameters, in which govern the engine characteristics and the effect of the combustion in the internal combustion engines. The combustion chamber piston crown design has a critical role in monitoring the mixing ratios of air and fuel[1]. It is crates a straight impact on the engine characteristics. An air movement create an important role in air and fuel mixture, rate of combustion and emission particles. The spray characteristics, spray angle, injection pressure and injection timing also have a significant role in diesel engine combustion with main factor of air movement. The different air motions such as squish, Swirl and tumble are the significant flow pattern. These flow patterns are not only affect the combustion process and air fuel mixing process in compression ignition engine. The air motions have a significant impact on combustion quality. The sufficient swirl motion of the air is to be attained with the proper intake port design. While there is swirl motion in the cylinder air, the swirl and squish motion contact created a turbulent flow at the end of the compression process[2]. This kind of different air motions takes place in the re-entrant piston shape dimension combustion chamber design. The improving process of turbulence motion is created high turbulent squish of the air near TDC of compression. The improvement of turbulence directs to created the proper combustion process and it is increases the NOx emission and fewer HC emissions. The investigator has not evaluated the effect of tumble motion[3]. The better air flow mixing and combustion characteristic processes are likely to have high injection pressure and it is produced the small amount of fuel droplets. The flow pattern of small fuel droplets have evaporative and mixing rapidly with air motion. The investigators have experimentally examined with various injection strategies for diesel engines. The multiple injections and extremely high injection pressures are the important factors in the diesel engines[4]. Many strategies are used to improve the engine characteristics by different piston crown geometries. It is utilized to produce high engine power. The report of the piston bowl dimension significantly affects the atomization and succeeding combustion process in direct injection compression ignition (DICI) engine[5]. The numerical analysis on the results of different swirl ratios on the piston crown combustion chamber design for a compression ignition engine. The conclusion of the initial swirl has a high impact on the pressure varies in cylinder and emission characteristics with ratio of large bore to piston bowl[6]. The numerical investigation of engine analysis has the different measurements of the re-entrant piston profile for turbo charged compression ignition engine[7]. The results of the enhancement in turbulence on the piston crown have an impact on fuel consumption and it is produced the emission particles of soot, and NO_x. The result of the various re-entrant bowl shape on the compression ignition engine and it is analysed that better swirl and turbulent kinetic energy occurred on the high re-entrant bowl and it is reduced the emission particles of NO_x and soot[7]. The combustion factors of performance and emission behaviours are found with various piston bowl parameters. The conclusion of the results exposed that the enhancement of toroidal radius, higher reduction of soot emission and better combustion efficiency[8].

The re-entrant combustion dimension is suitable to direct injection compression ignition engine caused by the emission of minimum soot particles and high pressure ranges in cylinder core. In recent research works, to analyse the results of variation in the engine compression ratio with various piston shape measurements on the evaluation of engine characteristics[9,10]. The rice bran methyl ester blends are used as a fuel in compression ignition engine with modification of piston shape dimension. Different compression ratio of the engine can be analysed with modification of the piston crown with help of molten wax method. The different shapes of pistons are Toroidal piston (TP) and Deep Toroidal Re-entrant piston (DTRP) from the baseline Hemispherical existing piston (HEP). The result of the engine characteristics of performance and emission particles for the different piston dimensions used in CI engine fuelled with various blends of RBBD/Diesel. Blend of RBBD with diesel in the percentage of 5%, 10% and 15% ratios. The results of engine characteristics are carried out at 20%, 40%, 60% and 80% loading state with different modification piston and existing piston.

Materials and methods

Biodiesel preparation and properties

Rice bran biodiesel is extracted from raw Rice bran oil with some catalyst process through transesterification process in which primary alcohol changes the triglyceride into glycerol and golden colour ester of vegetable oil as shown in Fig (1).The vegetable oil is collected in separate conical flask and maintained at 50°C, 60°C and 70°C. 2 gms of Sodium hydroxide and 400 ml methanol is mixed thoroughly to form Sodium methoxide solution and mixed with Rice bran in separate conical flask. The mixtures were maintained at 70°C, 80°C and 100°C respectively to initiate transesterification reaction in a rotating agitator for 8 hrs and transferred into an inverted separator. Settling period of one day is allowed and glycerol formation is removed[11,12]. The rice bran methyl esters are washed with 5% distilled water to remove the impurities. By this extraction method 92% of biodiesel is attained as shown in Fig (2).the different blend ratios of rice bran methyl ester properties are analysed and compared to diesel as exposed in Table1.

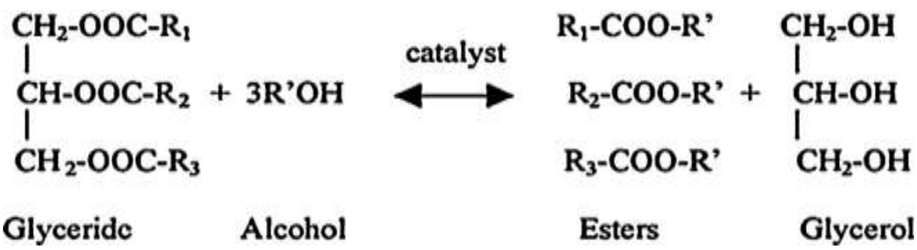

Figure 1.Common transesterification procedure

Figure2.Biodiesel preparation

Table.1 Properties of Rice bran methyl esters blends with diesel

S. No	Type of analysis	DIESEL	Rice bran methyl esters B5 Result	Rice bran methyl esters B10 Result	Rice bran methyl esters B15 Result
1	Acidity, Inorganic	Nil	Nil	Nil	Nil
2	Water content (KF titrator)	400 ppm	414 ppm	458 ppm	515 ppm
3	Density @ 15^0C in gm/cc		0.802	0.814	0.828
4	Kinematic viscosity @ 40^0C in CST	1.8	1.9	2.0	2.12
5	Ash content	Less than 0.001%	Less than 0.001%	Less than 0.001%	Less than 0.001%
6	Conradson carbon residue	Less than 0.001%	Less than 0.01%	Less than 0.01%	Less than 0.01%
7	Flash point (Abel)	66^0C	69^0C	71^0 C	73^0 C
8	Copper strip corrosion @ 100^0 C IN 3 hrs	No better than No.1	No better than No.1	No better than No.1	No better than No.1
9	Insoluble in hexane	0.096%	0.098%	0.001%	0.002%
10	Calculated cetane Index	46	48	51	54
11	Gross calorific value in kcals/kg	10000	12,990	11,550	10,970
12	Sulphur content	0.16%	0.21%	0.23%	0.25%

Modification of combustion chamber

The compression ratio of the engine can be varied by modification of piston crown measurements. The modified pistons are used to vary the compression ratio with molten wax method. The effects of the piston shape designs are found and compared to existing piston design[13]. These all experimental investigations are found on the KIRLOSKAR DM10 type diesel engine. The erosion and electrochemical metal deposition techniques are used to make the two different pistons such as TP and DTRP. The gas welding and machining process utilized to produce the complete piston shape dimensions[14,15]. Theexisting and modified piston shapes of HEP, TP and DTRP have the compression ratios of 16:1, 17.05:1 and 15.4:1 respectively as shown in Fig (3) to Fig (5). These two modified piston shape designs compared to the existing piston of HEP and they compression ratios are exposed in Table.2.The atomization of fuel spray is inspected in different geometries of piston shapes and the effect of evaluation process describes the variation in performance and emission characteristics[16,17].

Figure3.Hemispherical Existing piston

Figure 4.Toroidal piston

Figure 5. Deep Toroidal re-entrant piston

Table2. Compression ratio for the piston geometries

S.No	Piston Shape Designs	Compression Ratio
1	HEP	16.1
2	TP	17.05:1
3	DTRP	15.4:1

Experimental setup

The investigational engine testing is performed in KIRLOSKAR DM10 type, single cylinder, naturally aspirated water cooled diesel engine. Engine setup is attached to a DC dynamometer as a loading mechanism and running condition at the rate of constant speed of 1500 rpm. The engine specifications of bore, stroke length and cylinder capacity are found to be 102 mm, 118 mm and 984 cc respectively as given in Table 3.The compression ratio of the Existing industrial unit set engine has 16:1 with Hemispherical existing piston combustion chamber setup is also arranged which loads the engine and rheostat load stock also attached with it. The engine efficiency is accomplished with a burette stopcock with three way processes for every 10 cc fuel consumption time taken and it noted with help of the stopwatch[18,19]. The fuel injection timing of 15^0 BTDC and Bosch fuel injector is operated and AVL crank angle calculator and charge amplifier are also used for the transducer of kistler 701 was used to compute the combustion analysis of in cylinder pressure and this transducer equipped with cooling adapter and high temperature cables[20].The Crypton 290 type of five gas analyzer is used to examine the emission characteristics and mainly it is concentrated only on the engine emission characteristics such as HC, CO and NO_X as exposed in Fig (6).

Table 3.Specification of investigation engine

S.No.	Model And Make	Kirloskar DM10
1	No. of cylinder	single cylinder
2	Stroke (mm)	118
3	Bore (mm)	102
4	Maximum power (bhp)	10
5	Capacity (cc)	984
6	Injection pressure (bar)	190-200
7	Rated speed (rpm)	1500
8	Injection timing	15 btdc
9	Compression ratio (rc)	16.:1

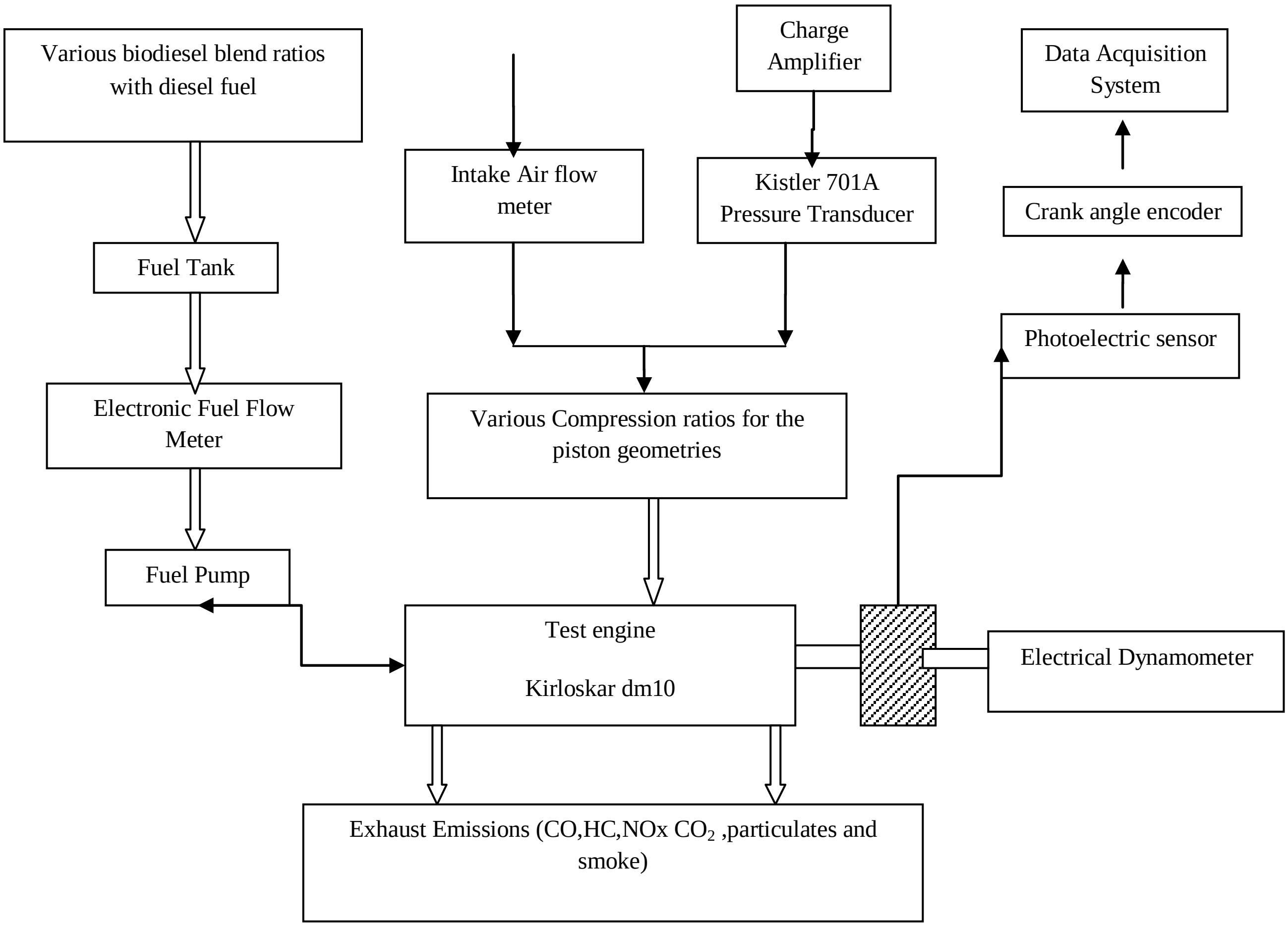

Figure 6. Schematic of experimental setup

Results and discussion

The experimental research parameters are analyzed with engine type KIRLOSKAR DM10 and various piston shape dimensions of HEP, TP and DTRP with the fuel of diesel and RBBD blend ratios. The important engine factors similar to Brake power (BP), Brake thermal efficiency (BTE), Oxides of carbon, unburned hydrocarbons and Oxides of nitrogen are examined for the declared combustion chamber.

Variation in performance parameters

Fig (7) to Fig (9)demonstrates the expected point out work produced from Existing piston and modified piston shapes with combustion chamber designs at the engine speed 1500 rpm under full load conditions. Hemispherical Existing piston is used in compression ignition engine fuelled with variety of RBBD blends such as 5, 10 and 15%. The study with variable compression ratio piston geometries shows that diesel-RBBD blend ratios with TP resulted in enhanced performance characteristics compared to the combustion chambers such as HEP and DTRP. At full load conditions, the BTE of HEP with diesel fuel and B5, B10 and B15 are found to be 29.5%,30.25%,31.5% and 32.67% in the order whereas TP shows 30.3%,30.6%,31.6% and 33% with diesel and RBBD blend ratios as shown in Fig(7) and Fig (8). The TP combustion chamber design in compression ignition engine has higher performance when compared to HEP and DTRP. Different RBBD blend ratios are used to achieve high BP and BTE[21]. The modified TP combustion chamber design shows variation in engine efficiency and establishes that increase in load conditions, the BTE also enhances with BP. The BTE of the RBBD is greater than diesel fuelat some load conditions. The efficiency of all piston dimension combustion chambers gives an increasing affinity with TP, which has higher BTE at part load conditions[22].

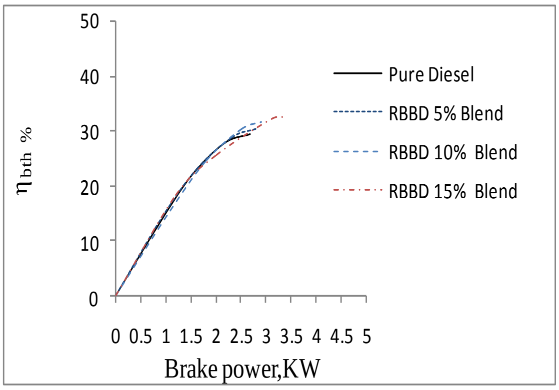

Figure7.Comparison of Brake thermal efficiency for Hemispherical Existing Toroidal piston with Diesel, RBBD 5%, 10% and 15% blend at full load.

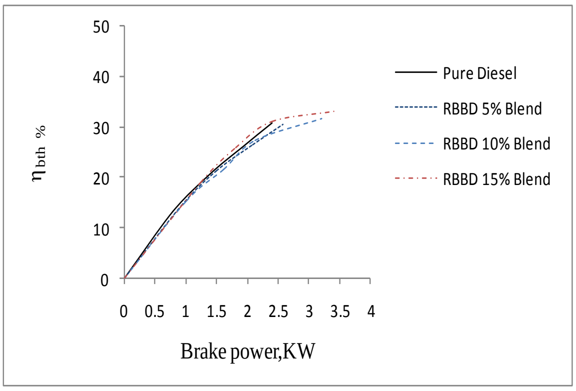

Figure8.Comparison of Brake thermal efficiency for Toroidal piston with Diesel, RBBD 5%, 10% and 15% blend at full load.

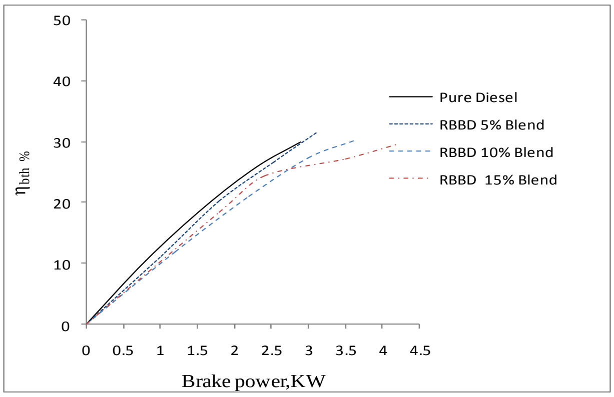

Figure9.Comparison of Brake thermal efficiency Deep Toroidal Re-entrant Piston with Diesel, RBBD 5%, 10% and 15% blend at full load

Additionally the observation of the results demonstrates that the BTE of DTRP with diesel and RBBD blend ratios gives 30%, 31.5%, 30.24% and 29.56% respectively whereas DTRP exhibited only 29.56% with B15 blend ratio. This may be due to worse combustion, swirl and squish produced in DTRPat the full load conditions[23]. DTRP exhibited a pessimistic raise in BTE at full load which could be due to reduced premixed combustion as shown in Fig (9).

Variation in emission parameters

CO emissions are toxic and have to be controlled. It is produced moreover directly or indirectly by combustion of fuels. In the perfect combustion process, carbon and oxygen (O_2) mingle to produce CO2. Imperfect combustion of carbon directs to CO formation. At no loading state, the emission is high in DTRP but after sometime it decreases gradually by increasing load. In HEP and TP, the emission characteristic reduces slightly by increasing the load. While comparing with the other two types, the TP type piston having less emission in various diesel and RBBD blend ratios as shown in Fig (10) to Fig (13).The emission characteristics of Fig. (10)Proves a decreasing trend of CO emissions across all the piston geometries with diesel and B5, B10 and B15 fuels. At part load the TP and DTRP showed 0.06% and 0.07% of CO emissions for diesel fuel. The HEP exhibits 0.065% of co emissions at partial loading conditions with diesel fuel. At full load the HEP exhibits 0.055% of CO emissions for diesel fuel .It has slighter amount of CO emissions compared to deep toroidal pistons. It is obvious that the TP emits lesser amount of CO for diesel which may be due to better oxidative steadiness and better swirl movement in cylinder core. At part load the TP and DTRP shows 0.05% and 0.07% of CO emissions for diesel and B5 Blend ratio respectively. The HEP exhibits 0.062% of CO emissions at part load conditions with diesel and B5 blend ratio fuel. At full load, the DTRP exhibits 0.06% of

CO emissions for diesel fuel. It has very higher amount of CO emissions compared to HEP. From the Fig (11) it is observed that DTRP emits higher quantity of CO for diesel and B5 blends which may be due to poorer oxidative constancy and not as good as swirl utilize in cylinder of the combustion chamber. At part load the TP and DTRP showed 0.045% and 0.07 % of CO emissions for diesel fuel and B10 Blend fuel. The HEP exhibits 0.052 % of CO emissions at part load conditions with diesel and B10 ratio. At full load the TP exhibits 0.02% of CO emissions for diesel fuel. It has very slighter quantity of CO emissions compared to HEP and DTRP as shown in Fig (12).At part load the HEP, TP and DTRP geometries showed 0.045% ,0.043% and 0.05% of CO emissions for diesel and B15 of RBBD Blend fuel respectively. At full load the HEP,TP and DTRP geometries exhibits 0.035%,0.025 % and 0.04% of CO emissions for diesel fuel respectively as shown in Fig (13).The TP has very slighter amount of CO emissions compared to other piston geometries[24] .

In HEP, the HC emission characteristics is low in no load condition for various extend and gradually increasing by increasing the load after reaching a particular point maintained constant using diesel and biodiesel blend ratios[25]. In particularly TP piston have fewer amounts of HC emissions to compare the HEP and DTRP.The Fig (14) shows a decreasing trend of HC emissions across all the loads in HEP, TP and DTRP geometries with diesel. At partial loading condition the TP shows lesser amount of HC emission emitted in the range of 17 ppm compared to HEP and DTRP has 18 ppm and 24 ppm respectively. At full load condition the HEP and DTRP shows 26 ppm and 28 ppm of HC emissions for diesel respectively.

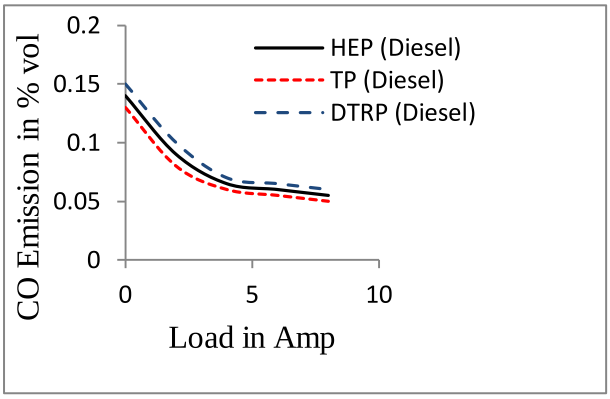

Figure10.Comparison of CO emissions for different shape of pistons with Diesel at various loads

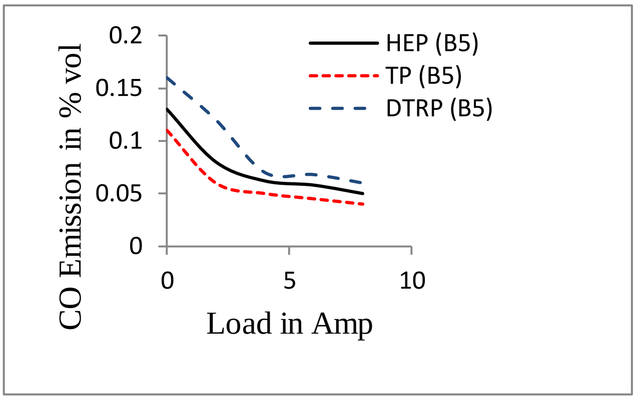

Figure11.Comparison of CO emissions for different shape of pistons with Diesel, RBBD 5% Blend at various loads

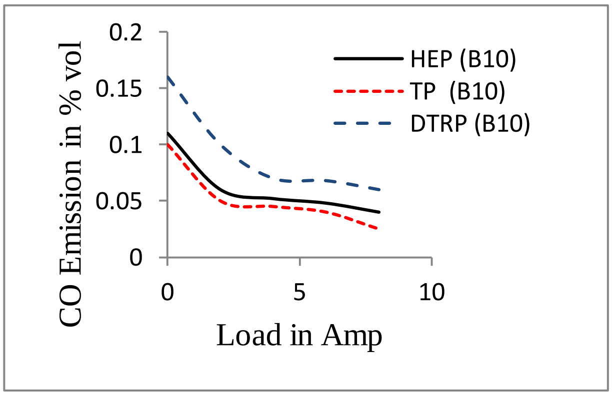

Figure 12.Comparison of CO emissions for different shape of pistons with Diesel, RBBD 10% Blend at various loads

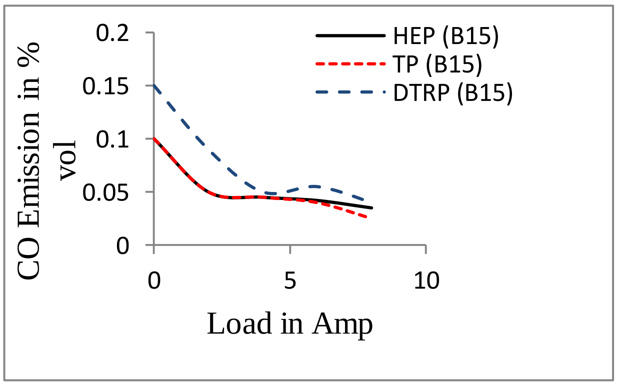

Figure13.Comparison of CO emissions for different shape of pistons with Diesel, RBBD 15% Blend at various loads

The TP shows lesser amount of HC emission in the range of 24 ppm at full load[26].From Fig (15) it is evident that the TP emits lesser amount of HC for diesel and B5 blend ratios. The TP exhibits 17 ppm of HC emissions at part load condition with diesel and B5. At the same load the HEP and DTRP exhibits 18 ppm and 19 ppm of HC for diesel and B5 Blend ratio respectively. TP with diesel and B5 were found to emit 26 ppm of HC during full load condition which is very lower than HEP and DTRP. From the Fig (16) the TP emits lesser amount of HC for diesel and B10 blend ratio. TP with diesel and B10 blend ratio were found to emit 17 ppm of HC during part load condition and 25 ppm during full load condition. At full load the HEP and DTRP showed26 ppm and 28 ppm of HC for diesel and B10 blend ratio. Fig (17) proves the effect of TP emits slighter amount of HC for diesel and B15 blend ratio. At part load condition the HEP and DTRP exhibits 20 ppm and 22 ppm of HC for diesel and B15 blend ratio. The TP with diesel and B15 were found to emit 19 ppm of part load and 26 ppm during full load condition which is lower than the HEP and DTRP. In no loading condition high amount of HC happen, because large amount of fuel intake in no load condition. If the fuel supply is more in high load condition the HC emission will raise. The emission reduces as load increases in all piston dimensions. The HC emissions are low in the TP when compared with other two pistons with diesel and RBBD blend ratios[27].

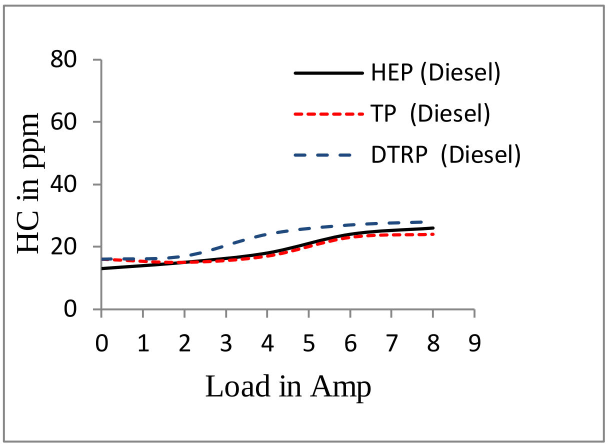

Figure.14 Comparison of HC emissions for different shape of pistons with Diesel at various loads

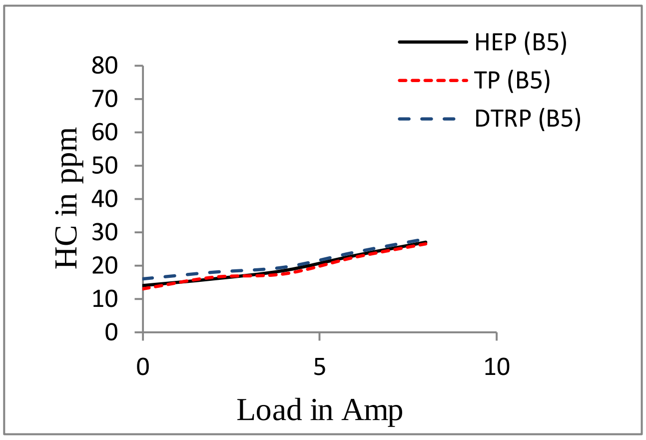

Figure15.Comparison of HC emissions for different shape of pistons with Diesel, RBBD 5% Blend at various loads

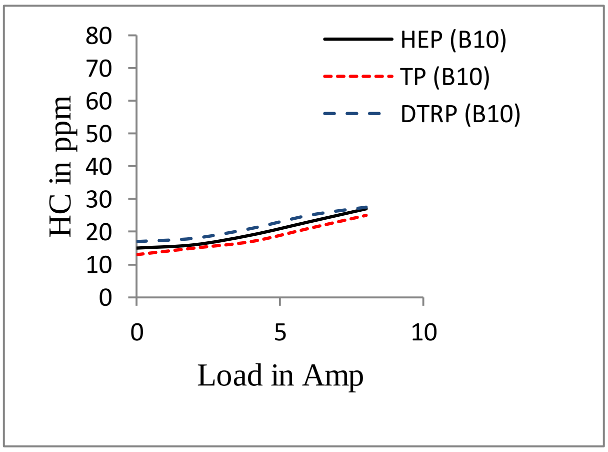

Figure16.Comparison of HC emissions for different shape of pistons with Diesel, RBBD 10% Blend at various loads

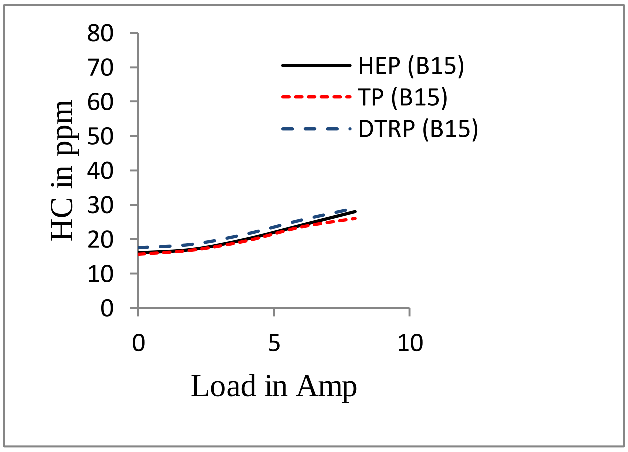

Figure17.Comparison of HC emissions for different shape of pistons with Diesel, RBBD 15% Blend at various loads

The difference in NO_X with loading condition can be seen from this Fig (18) to Fig (21) that the maximum NO_X values were attained with the blend ratios. In addition, NO_X emission of the diesel fuel was lower than that of the biodiesel blend ratios. NO_X emission slightly increases due to higher combustion temperature and the occurrence of fuel oxygen with the blend ratios at all load conditions. The above figures demonstrate the difference in NOx for all piston shape dimensions with diesel and RBBD with Blend ratios. The HEP piston with diesel fuels exhibits 427 ppm and 686 ppm at part and full load respectively.

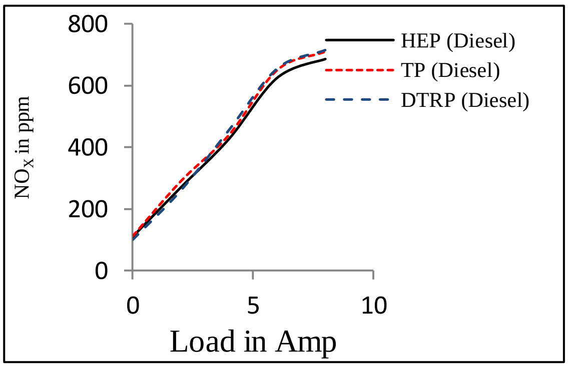

Figure18.Comparison of NO_X emissions for different shape of pistons with Diesel at various loads

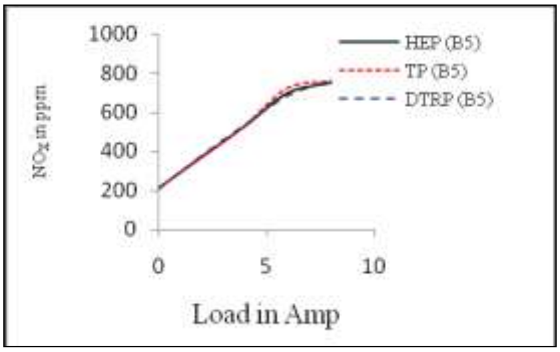

Figure19.Comparison of NO_X emissions for different shape of pistons with Diesel, RBBD 5% Blend at various loads

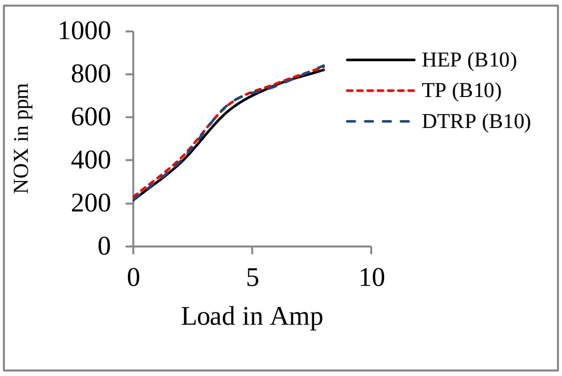

Figure20.Comparison of NO_X emissions for different shape of pistons with Diesel, RBBD 10% Blend at various loads

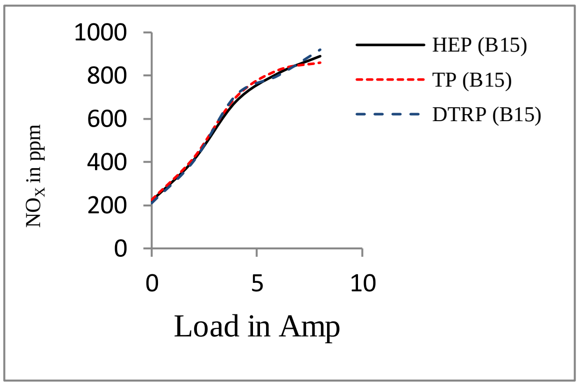

Figure 21.Comparison of NO_X emissions for different shape of pistons with Diesel, RBBD 15% Blend at various loads

The TP and DTRP piston dimensions with diesel were create to emit 440 ppm and 456 ppm during part load conditions 710 ppm and 716 ppm during full load conditions which is higher than HEP geometry as shown in Fig (18). It is observable than HEP emits lesser quantity of NO_X for diesel fuel. The HEP with diesel and RBBD with B5 fuel shows 528 ppm and 752 ppm at part and full load conditions respectively as shown in Fig (19). The TP and DTRP dimensions with diesel were found to emit 530 ppm and 535 ppm during part load conditions as well as 759 ppm and 762 ppm during full load conditions which is higher than the HEP. It is noticeable that the HEP emits lesser quantity of NO_x for diesel and RBBD with B5.The TP with diesel and blend ratios showed 658 ppm and 834 ppm at part and full load conditions respectively. The DTRP dimensions with diesel were found to produce 660 ppm during part load condition 840 ppm during full load condition which is higher than TP.From the Fig (20) it is observable that HEP emits lesser quantity of $NO_x$for diesel fuel and B10 Blend ratio. The TP with diesel and B15 fuel demonstrates 670 ppm and 860 ppm at part and full load respectively. The DTRP with diesel and B15 were found to emit 700 ppm during part load condition 910 ppm during full load conditions which is higher than the TP and HEP dimensions. From the Fig (21)it is apparent that the TP emit lesser quantity of $NO_x$for diesel fuel and B15 Blend ratio. The DTRP exhibits higher amount of NO_x for all load conditions. Generally DTRP was not suitable at part and full load states on comparison with TP and HEP[28].

Conclusion

The main aim of this study was to investigate the suitability of Rice bran methyl ester blends in compression ignition engine under variable piston dimension. The BTE of TP dimension with RBBD with B15 was found to be 33% were as HEP and DTRP showed 32.67% and 29.56 % respectively at full load conditions. The BTE was found to be improved between 10 to 15% for TP on compared with HEP and DTRP which were due to high calorific value of RBBD with B15 and higher swish and swirl motion for TP dimension combustion chamber design. As RBBD controlled more oxygen, the CO emission was reduced in TP geometry by 5% to 7%. DTRP demonstrated high CO emission which was due to improper mixing of air and fuel. The variation of HC was also found to be better in TP than HEP and DTRP at part load and full load operations. The HC emission for TP was 24 ppm and 26 ppm for diesel and biodiesel blend at full load which was due to the result of wall quenching and incomplete combustion. The NO_x emission was found to be higher at all loads for DTRP than HEP and TP geometries which was due to lack of oxygen at higher temperature, higher swirl and swish. The present study finally exposes that TP dimension combustion chamber was found more suitable with blends of RBBD at part and full load conditions due to improved mixing of air-fuel ratio and high swirl and swish air movement in combustion chambers.

Abbreviations and Nomenclature

BTDC	Before top dead center
RBBD	Rice bran Biodiesel
BP	Brake Power
BTE	Brake Thermal Efficiency
TP	Toroidal Piston
HEP	Hemispherical Existing Piston
DTRP	Deep Toroidal Re-entrant Piston
B5	5% Blend
B10	10% Blend
B15	15% Blend
CO	Carbon Monoxide
NOx	Oxides of Nitrogen
HC	Hydrocarbons

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