PERFORMANCE AND EMISSION ANALYSIS OF THE DIESEL ENGINE WITH THE MODIFIED PISTON RUN BY DELONIX REGIA OIL

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ABSTRACT

In this study, the performance and emission characteristics of a single cylinder diesel engine with the effect of piston bowl geometry [Hemispherical Cavity Piston (HCP) and Toroidal Cavity Piston (TCP)] using diesel and Delonix regia. Then its diesel blends have been mixed under different loading conditions. The Delonix regia oil is converted into Delonix regia by trans-esterification process and then used to prepare biodiesel/diesel blends. Then the base engine hemispherical cavity piston is machined to make toroidal type piston without affecting its cavity volume and without affecting the compression ratio of the engine. The blend used in this engine are Diesel,B25+75%diesel,B50+50%diesel,B75+25%diesel and B100. The results showed that the brake thermal efficiency of neat Delonix regia biodiesel and its blends for Toroidal Cavity Piston operation was increased and the CO, HC and smoke emissions were decreased at full load. The NOx emissions were slightly increased for Delonix regia seed oil and its diesel blends with toroidal piston operation compared with diesel fuel with HCP operation.

KEYWORDS: *Modified Piston, Delonix regia, Trans-esterification, Biodiesel.*

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1. INTRODCTION

As the decreasing trend of world global petroleum reserves and environmental degradation resulting from the combustion of petroleum fuels in transport vehicle and power plant becomes more apparent, so it is necessary to find alternative sources of energies like biofuels and biomass. Biofuels is the only viable choice of renewable energy for use in transport vehicle that do not require any hardware modifications in vehicle design.

But some biomass alternatives such as ethanol, methanol and biodiesel derived from delonix regia oil . The raw delonix regia oil is extracted from oil seeds by crushing and other methods. The properties of raw delonix are closer to diesel fuel except its kinematic viscosity. The kinematic viscosity of raw oil is reduced by trans-esterification process to convert into delonix regia oil.

In the last two decades, many researchers have studied that biodiesel fuels produce no sulfur dioxide and less aromatic hydrocarbon emissions. They are renewable, less toxic, and biodegradable and their combustion characteristics are comparable with with petroleum diesel fuels. In addition to that the biodiesel properties are similar to that of petroleum diesel fuels and they can be used as sole fuel or blended with diesel in diesel engines without any modification. The use of raw delonix oils used as fuel for diesel engines without modification causes some damage to parts of the engine and also, the performance is greatly affected . Various researchers have conducted experiments to study the performance and emission characteristics of diesel engine when delonix oils, blends of delonix seed oil and its derivatives are used as fuel and it has been found to be economical and competitive compared to petroleum diesel fuel. Forson have investigated that diesel engine running with oil and diesel blends produces a closer performance and emissions characteristics to diesel for lower blend concentration of delonix oil. The performance tests using blends of diesel and delonix oil in a single-cylinder CI engine. The results showed that specific fuel consumption and the exhaust gas temperature were reduced due to decrease in viscosity of the delonix oil. Therefore, the main objective of the present study is to decrease the viscosity of delonix oil by blending with diesel and to evaluate the engine performance and emission characteristics without any substantial hardware modifications.

2. Materials and Methods

2.1 Seed Preparation, oil extraction and characterization

Dry fruits of *Delonix regia* were collected from different areas in Akwa Ibom State. Fruits were split opened to obtain the seeds which were sun dried and stored in dry bottles until when needed. De-shelled seeds were ground with a mechanical grinder and 200g of the grinded seeds were packed in filter paper which was then inserted into a wheaton soxhlet extractor using 150ml of hexane as extracting solvent at 60oC. This process was carried out for 9hrs and the solvent was recovered by simple distillation. The oil was filtered using a cartilage filter to remove solid debris and the distilled residual oil was heated at 100oC for 1hr in order to remove any water molecules. The oil was then cooled and stored in sealed plastic bottles until when required. Four physical properties (kinematic viscosity, density, flash point and total acid content) of the seed oil were determined. The ASTM D1298 and D445 were used in measuring the density and viscosity respectively while flash point and the acid content were determined using ASTM D93 and ASTM D methods respectively

2.2Preparation of sodium methoxide and potassium methoxide

20g of methanol was mixed with 1.61g of NaOH alkaline pellets with stirring continuously until all the pellets have dissolved. This reaction forms sodium methoxide. Caution was taken in handling the oxide. Since alcohols can evaporate easily, the flask was covered with conical glass during shaking to reduce the loss of alcohol. This covering was also to prevent from absorbing water from the air. The above process was adopted for the preparation of potassium methoxide

2.3Basic Titration

This is carried out to determine the number of grams of NaOH that will be used per litre of oil in the transesterification process. With this process a rough estimate of the quantity of catalyst to be used for optimization. A 0.1 solution of NaOH was prepared by dissolving 1g of NaOH in 1litre of water. In another beaker, 1ml of *Delonix* oil was dissolved in 10ml of pure iso-propal alcohol. The content was warmed gently in hot water stirred until all of the oil had dissolved in the alcohol and the mixture turned clear. 2 drops of phenolphthalein solution was used as indicator. With the help of a burette, 0.1% NaOH solution was added drop by drop with stirring until the solution stays pink for 10 seconds. The number of mls of 0.1% NaOH solution used added to 5.0 will give the number of NaOH to be used per litre of oil .

2.4Transesterification process and separation of ester

Transesterification of the first batch of *D. regia* seed oil was carried out with methanol in the presence of NaOH as catalyst. This method investigates the reactions were conducted in batches at 6:1 methanol to oil molar ratio, 1% catalyst and 65oC temperature. The oil was first heated to this temperature in an oven with stirring at intervals. 240g of seed oil was charged into a 500ml rector and then heated in a water bath to the desired temperature. 40g of methanol and NaOH (1% weight of oil) were mixed and heated to the desired temperature in a separate container. This mixture was then poured into the reactor placed in an electric mixer and magnetic stirrer. The stirring speed was maintained at 400rpm and the reaction was carried out for 5hours. After the reaction the contents were allowed to cool under air current. This solution was then poured into a separating funnel and separation was allowed to take place under gravity for 10 hours. The methyl ester (biodiesel) was found floating on top while the denser glycerine, excess alcohol, catalyst, impurities and traces of un-reacted oils settled at the bottom of the funnel. Solidified glycerine in the funnel was removed by reheated just enough to liquefy it. The separated biodiesel layer was then mixed and washed with warm distilled water to remove un-reacted alcohol, oil and catalyst. Before washing for the first time, a small amount of dilute acetic acid was added to neutralize possible effects of any NaOH that may be present in the biodiesel. The biodiesel obtained was then used for characterization. Before, characterization of produced biodiesel, the percentage conversion of the oil to biodiesel was determined using the equation:

%Conversion = (volume of biodiesel produced /volume of oil used) *100

3.Characterization analysis

3.1Biodiesel Characterization

The physical and chemical properties of biodiesel were investigated. The parameters assessed included; colour, viscosity, density, acid value, flash and clod points, pour point, sulphur, moisture and ash content, carbon residues as well as gross heat of combustion. Biodiesel colour was determined using the ASTM D method while the density and kinematic viscosity were measured using ASTM standards D1298 and D445 respectively. Cloud, pour and flash points were determined using the ASTM methods D5949, D5773 and D 93 respectively.The Total acid number was measured using the ASTM D method while the carbon residue and gross heat of combustion were assessed using the ASTM D189/IP 13, ASTM 4868 and ASTM D482/IP respectively. The sulphur, moisture and ash contents were determined using Acq method sulphur M, ASTM D and ASTM D482/IP methods respectively .

3.2Optimization of reaction conditions

With respect to optimization, five parameters; molar ratio of alcohol: oil, temperature, catalyst concentration, reaction time and rate of agitation were investigated. The effect of each factor was assessed by varying one of the above parameters while keeping the others constant. The molar ratio of alcohol: oil was determined at 7.1, 6:1, 5:1, 4:1 and 3:1 while, temperature was examined at 45oC, 50oC, 55oC, 60oC and 65oC. Catalyst concentration was tested at 0.6%, 0.7%, 0.8%, and 0.9%. The reaction time was investigated at 30, 40, 50, 60 and 70min, while, the effect of agitation was studied at 700, 600, 500, 400 and 300 rpm. All experiments in this study were conducted in three replicates and results analysed using ANOVA.

Table-1: Triation result

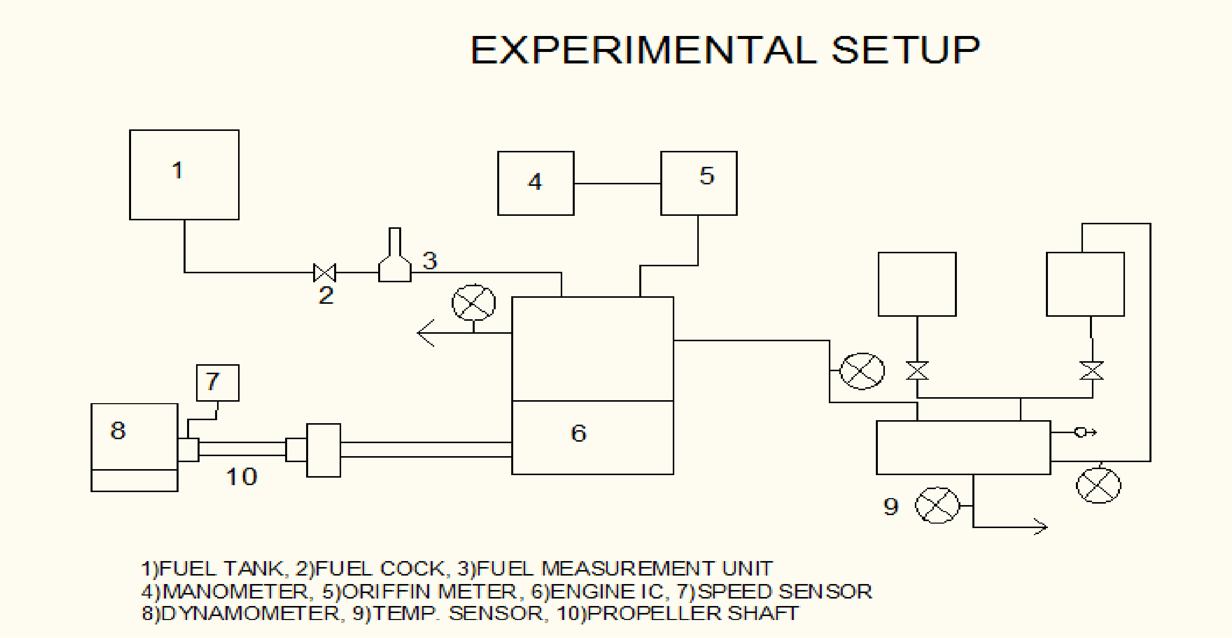
	VOLUME OF NAOH (ml)			
SAMPLES	**INITIAL**	**FINAL**	**VOL USED**	**REQURIED MASS**
A	55.0	56.4	1.7	7.0
B	50.0	51.3	1.3	6.2
C	60.0	62.8	1.6	6.5
AVERAGE	55.0	56.8	1.5	6.5

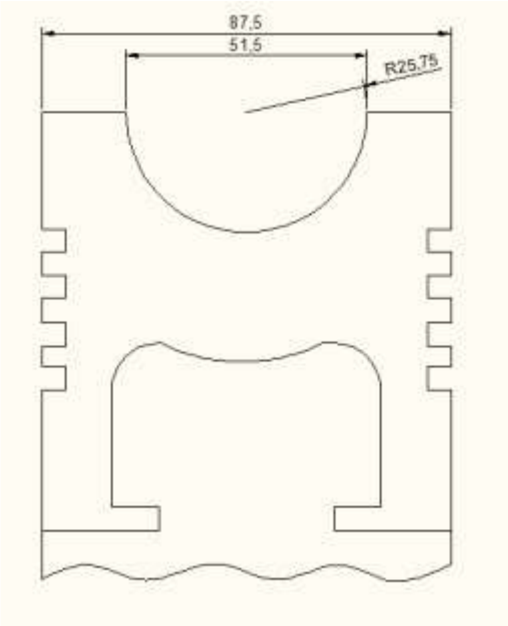
Table-2: physical charaterics of seed oil

PROPERTY	**DELONIX REGIA OIL**	**ASTM BIODIESEL VALUE**
Total acid number Mg of NaoH/g	0.95	0.124
Flash Point (^{o}C)	195	76.6
Density at 25^{o}C	895	820-890
Kinematic Viscosity at 25^{o}C(mm^2/s)	37.3	1.5-5.6

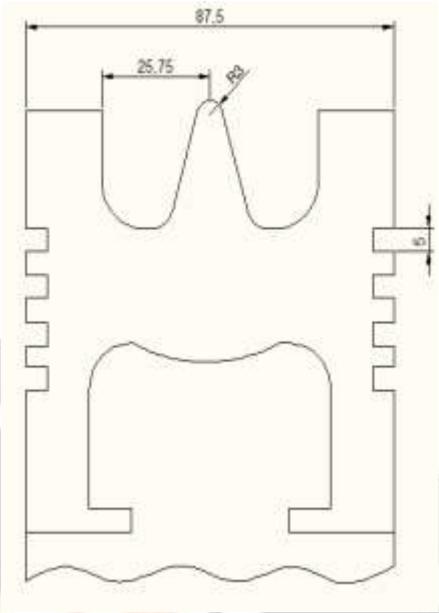
4.Experimental Setup

In this experimental work, a Kirloskar make single cylinder, four-stroke, compression ignition (CI), air cooled diesel engine was used. The specifications of test engine are given below. The test engine was coupled with electrical dynamometer with load bank to apply the brake load to the engine. Two separate fuel tanks are used for diesel and biodiesel. The fuel flow was measured with the help of burette and stopwatch. The standard Kirloskar engine has Hemispherical Combustion Chamber (HCC) with overhead valve arrangements operated by push rods. The exhaust gas emissions like CO, HC and NOx were measured by AVL-444 five gas analyser and smoke intensity was measured by AVL 437C Smoke meter. The accuracy of the gas analyser . The modifications of the piston made without altering compression ratio of engine, piston's combustion chamber geometry with Toroidal Combustion Chamber (TCC) from the base ENGINE piston cavity HCC. HCC also give small squish. However, depth to diameter ratio can be varied to give any desired squish to give better performance. But the toroidal piston provides a powerful squish along with the air movement inside the combustion chamber, resulting in better utilization of oxygen in the toroidal combustion chamber.





(Hemispherical) HCP



(Toroidal) TCP

Table-3

Engine	**Value**
No. of Cylinder	1
No. of Strokes	4
Fuel	HS diesel
Rated Power	5.2KW(7hp)@1500rpm
Cylinder Dia.	0.0875m
Stroke Length	0.11m
Compression ratio	17.5:1
Air Measurement of orifice Dia.	0.02m
Dynamometer Arc Length	0.195m

5.RESULT AND DECISION:

5.1Brake thermal efficiency Vs BP:

The brake thermal efficiency with brake power for diesel and delonix regia oil methyl ester for both the piston operations. The brake thermal efficiency of B25,B50,B75 and B100 with base engine (having HCP piston) is lower compared to that of diesel. Since the engine is operated under constant injection timing and the COME has a smaller ignition delay. Due to this the combustion is initiated much before TDC is reached. This increases compression work and more heat loss and thus reduces BTE of engine. The BTE for TCP with B25 and B100 is higher than base engine with HCP piston at all loads. This may be due to air-fuel better mixture formation of B25,B50,B50 and B100 with air, as a result of better air motion in TCP piston, which leads to better combustion of COME and thus increases the brake thermal efficiency at full load. The BTE of B25 andB100 with TCP piston operation is increased by 3.6% and 3.33% respectively compared with the same fuel with HCP piston. The maximum efficiency obtained for B25 with TCC piston is 36.03%, whereas for HCP piston it is 34.14% at maximum load.

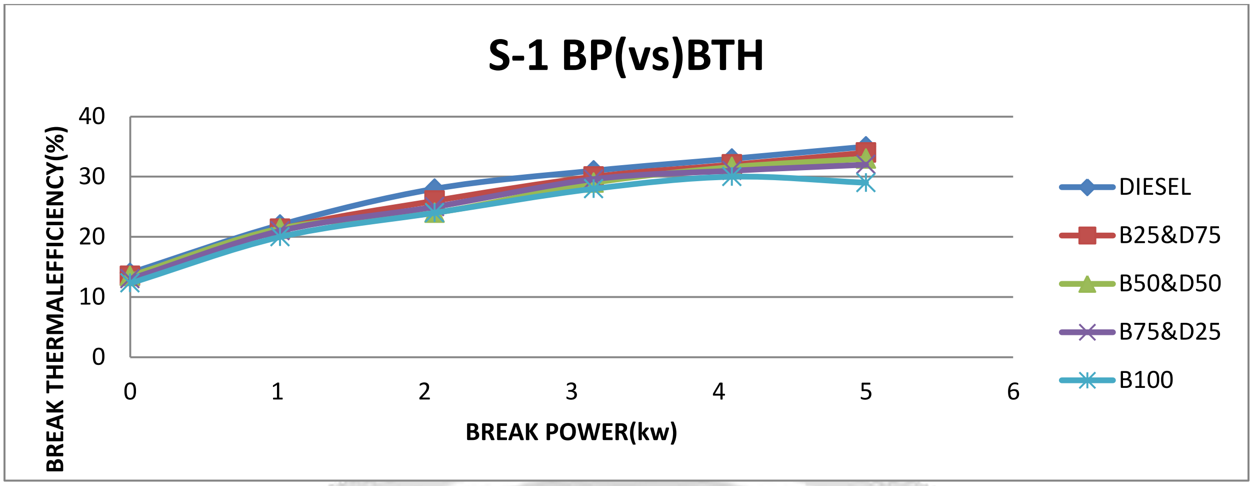


Chart-1: Normal piston

(VS)

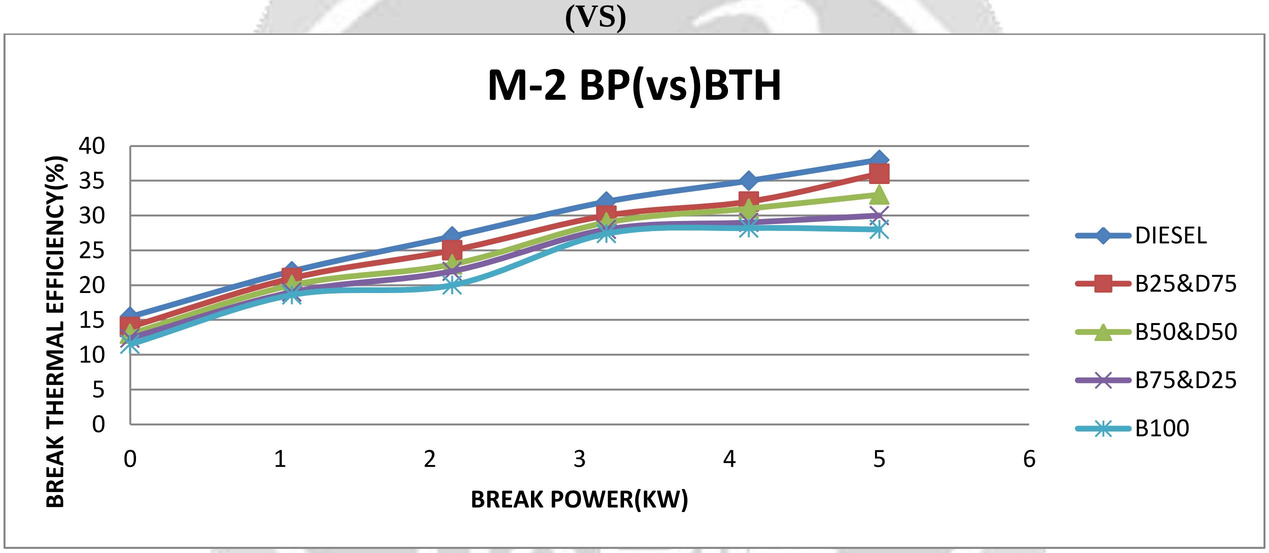


Chart-2: Modified piston

5.2Brake specific fuel consumption Vs BP:

The variation of brake fuel consumption (BSFC) with brake power for the test fuels with both the piston operations. At full load, the BSFC for B25 is slightly higher than that of diesel base engine with HCP piston at full load. This may be due to lower calorific value of COME compared with diesel fuel. The BSFC is slightly decreased when the engine is operation with TCP piston using B25 and B100 biodiesel. The BSFC of TCP piston B25 is 0.35kg/kWh,B50 is 0.37kg/kwh,B75 is 0.40kg/kwh & B100 is 0.41kg/kwh and with HCC is B25-0.376kg/kWh,B50-0.378kg/kwh,B75-0.39kg/kwh& B100-0.42kg/kwh. whereas for diesel with base engine is 0.291kg/kWh at full load. The BSFC of B100 with HCP and TCP is lower than that diesel fuel with base engine at full load.

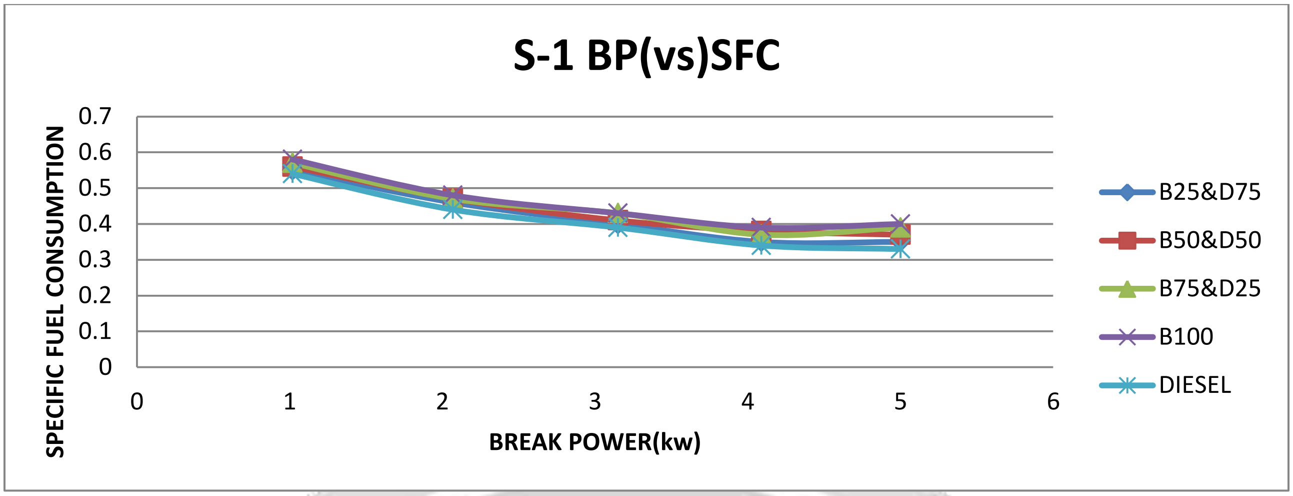


Chart-3: Normial piston

(VS)

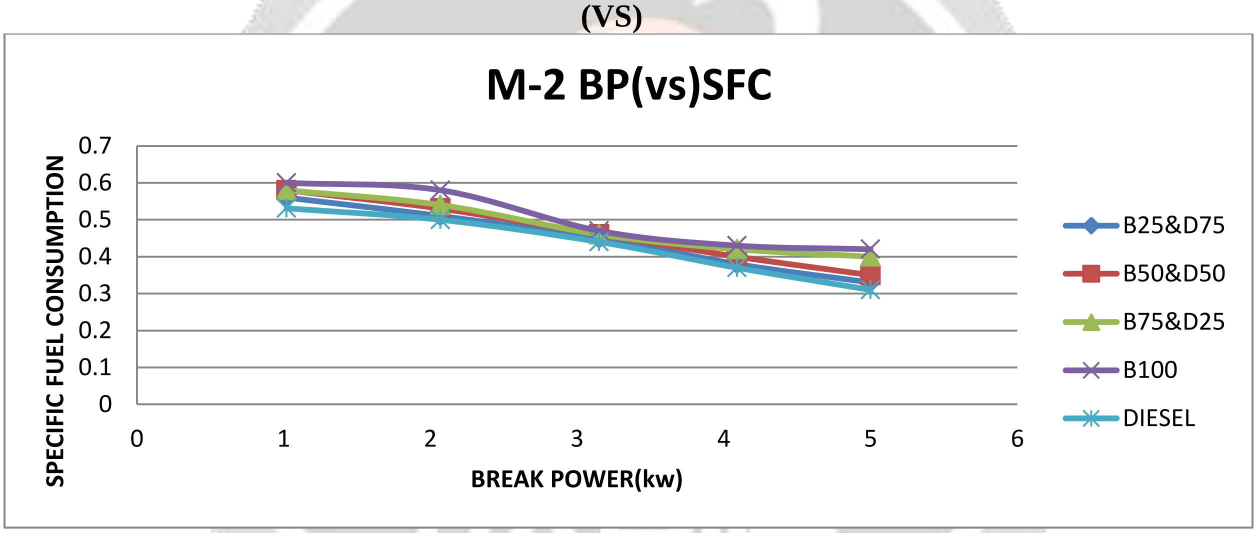


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Chart-4: Modified piston

5.3Exhaust gas temperature Vs BP:

Exhaust gas temperature variations for the diesel and biodiesel blends for both the piston operations. It is observed that exhaust gas temperature increases with increase in load for both the pistons for diesel and biodiesel and its blend. It is also observed that exhaust gas temperature increases for all fuels due to more amounts of fuel burns at higher loads. The exhaust gas temperature is slightly decreased for B25 and B100 with TCP piston operation compared with HCP piston. The increase in exhaust gas temperature may be due to better air motion in the TCP and higher oxygen content present in the biodiesel, resulting in better combustion, and thus decreases the exhaust gas temperature. The exhaust gas temperature for B25,B50,B75 and B100 with TCP is 310,319,335 and 340, whereas for HCP it is 315,335,340 and 325 respectively at full load.

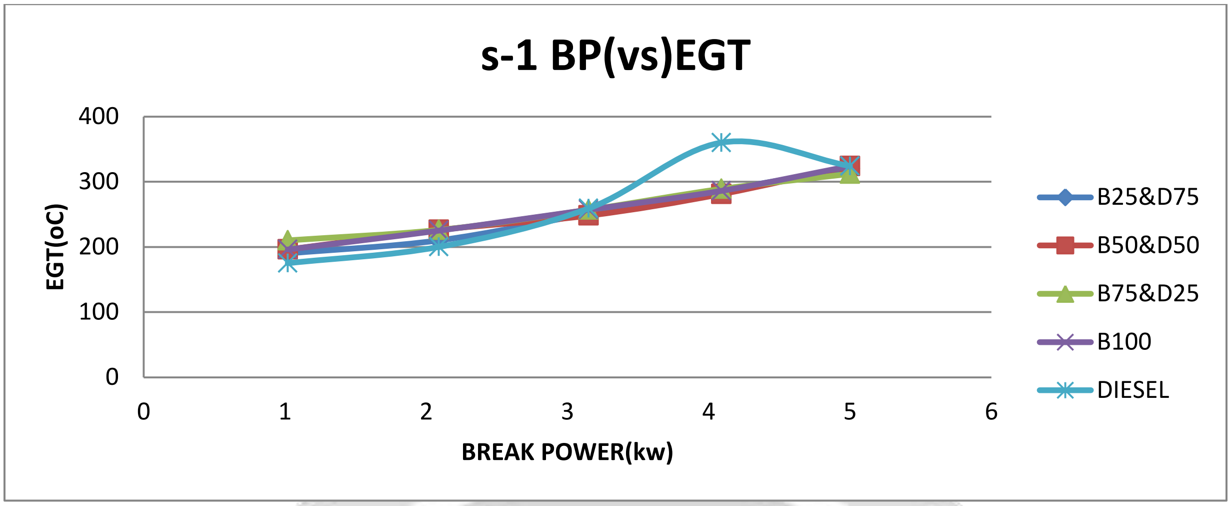

Chart-5: Normial piston

(VS)

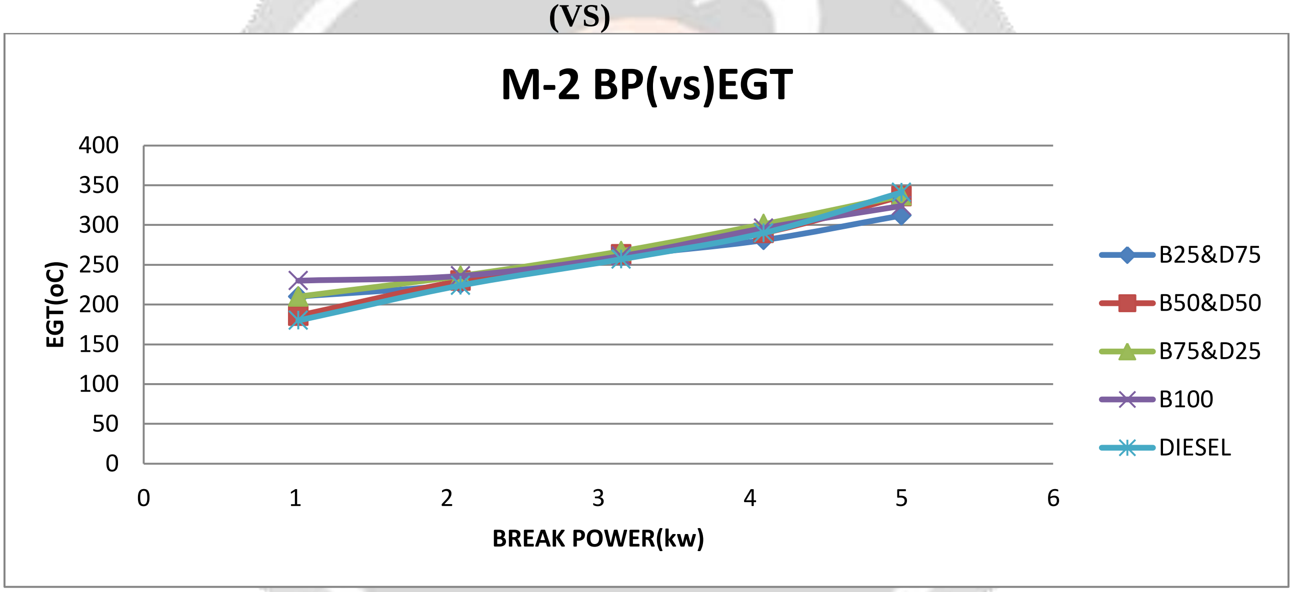

Chart-6: Modified piston

5.4Carbon monoxide emission Vs BP

Carbon monoxide emissions with brake power for all test fuel with both the piston operations. The CO emissions for both the combustion chambers are not much different from those of diesel fuel at all loads. However, CO emissions of the B25 and B100 decreased significantly when compared with base line diesel fuel at full load. The CO emissions for B25 and B100 further decreased with TCP when compared to HCP at full load. This is due to higher air movement in TCP and presence of oxygen in the COME biodiesel, lead to better combustion of fuel, resulting in decrease in CO emissions. The maximum reduction in CO emission for B25 and B100 with TCP is 30% and 40% respectively when compared with HCP piston operation. The CO emission obtained for B25,B50,B75 and B100 with TCP is0.09%Vol,0.11%vol,0.16%vol and 0.16%Vol, where as with HCP it is 0.12%Vol,0.10%vol,0.11%vol and 0.12%Vol respectively at full load.

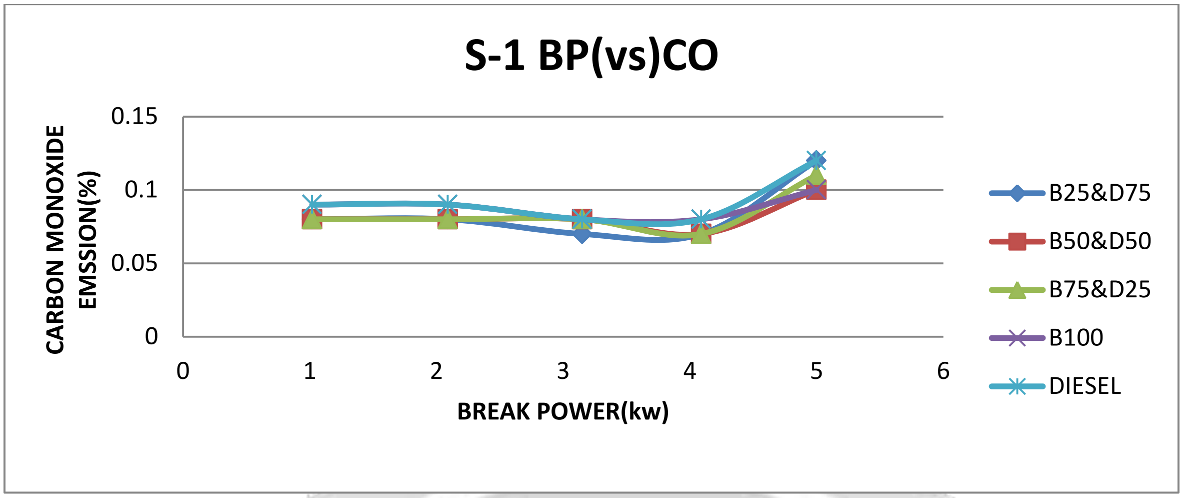

Chart-7: Normal piston

(VS)

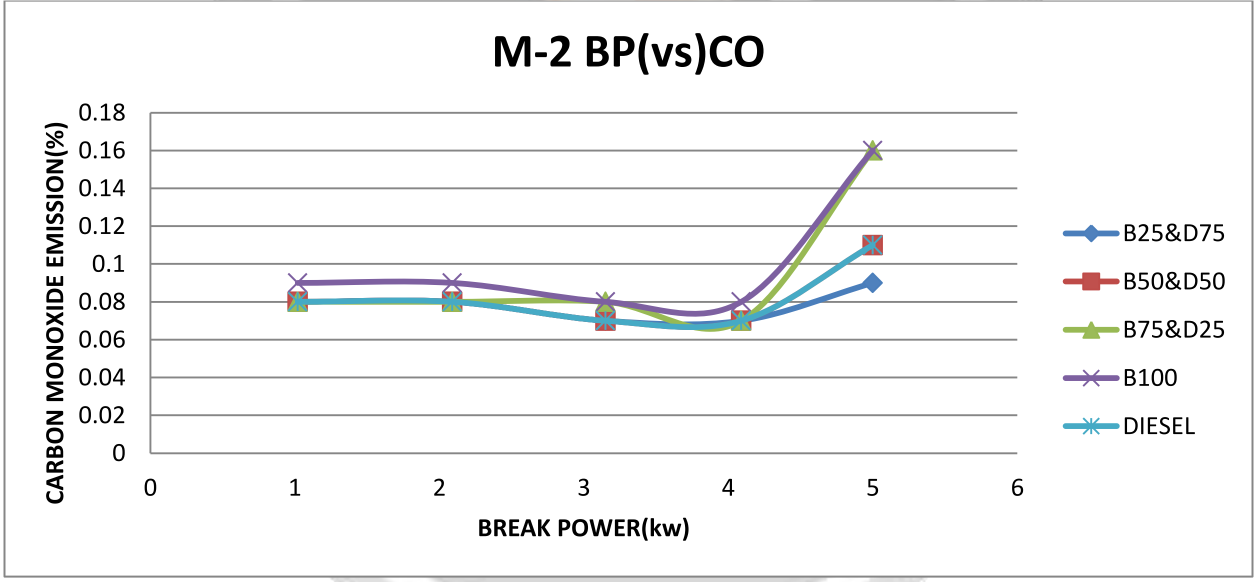

Chart-8: Modified piston

5.5Hydrocarbon emission Vs BP:

Variation of hydrocarbon emissions with brake power for all the test fuels with both the piston operations. The HC emissions of the B25 and B100 decreased significantly when compared with base line diesel fuel at full load. The HC emissions for B25 and B100 further decreased with TCP when compared to HCP at full load. This is due to improved swirl motion of air movement in TCP and presence of oxygen in the COME biodiesel, lead to better air-fuel mixture formation, resulting in complete combustion of fuel. The maximum reduction in HC emission for B25 and B100 with TCP is 14% and 15% respectively when compared with HCP piston operation. The HC emission obtained for B25,B50,B75 and B100 with TCP 63 ppm,90 ppm,89 ppm and 60 ppm, whereas with HCP it is 80 ppm,77ppm,72 ppm and 90 ppm respectively at full load.

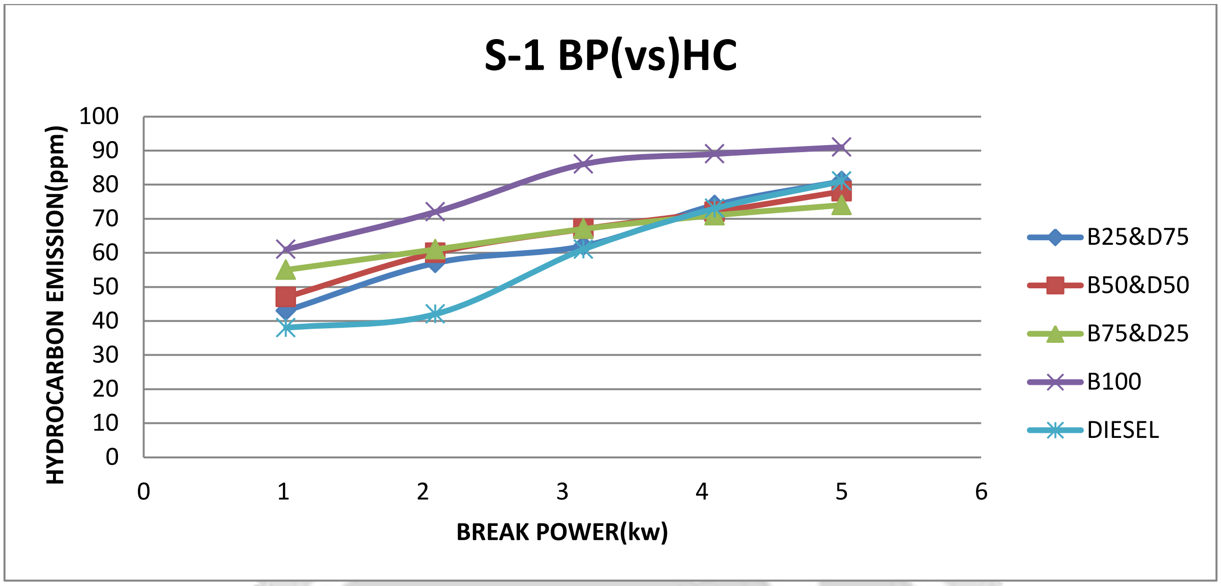

Chart-9: Normal piston

(VS)

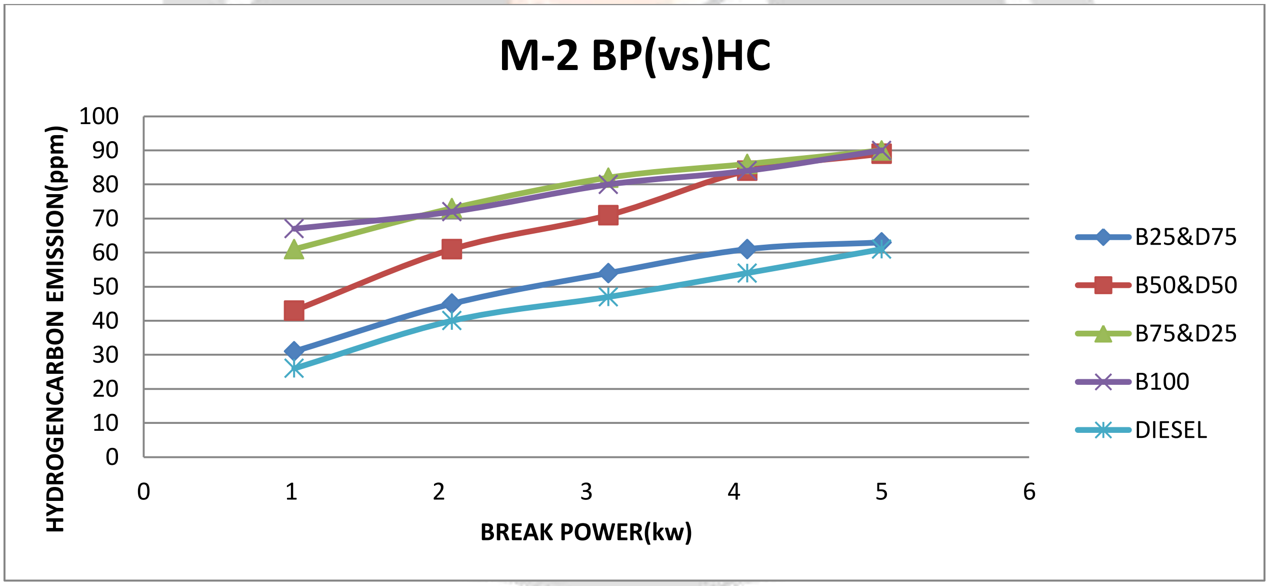

Chart-10: Modified piston

5.6Nitrogen oxide emission Vs BP:

Depicts the variation of nitrogen oxide emissions with brake power for all test fuel with both the piston operations. The NO emissions for B25 and B100 were higher for TCP piston than the base engine with HCP piston operation. The NO emissions increased by 0.4% and 0.5% for B25 and B100 with TCP compared with HCP operation. The reason for increase in NO emissions may be due to higher combustion temperatures by better mixture formation and availability of oxygen in COME resulting in improved combustion. The another reason for increased in NO emissions may be due to lower ignition delay resulting in larger part of combustion is completed before top dead center for biodiesel fuels compared to diesel. So it is highly possible that higher peak cycle temperatures are reached for biodiesel fuels. However, the NO emission can be controlled by adopting exhaust gas recirculation (EGR). For

B25,B50,B75 and B100 with TCP, the NO emission was 970 ppm,950 ppm,900 ppm and 825 ppm compared to 975 ppm,825 ppm,790 ppm and 730 ppm respectively for base engine with HCP at full load.

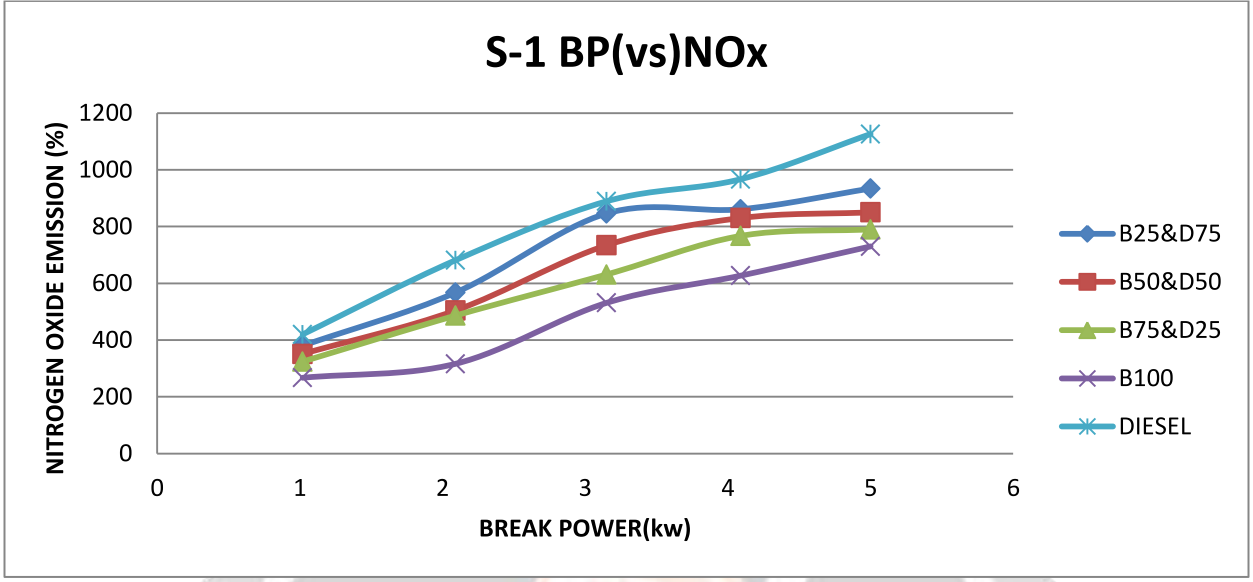

Chart-11: Normal piston

(VS)

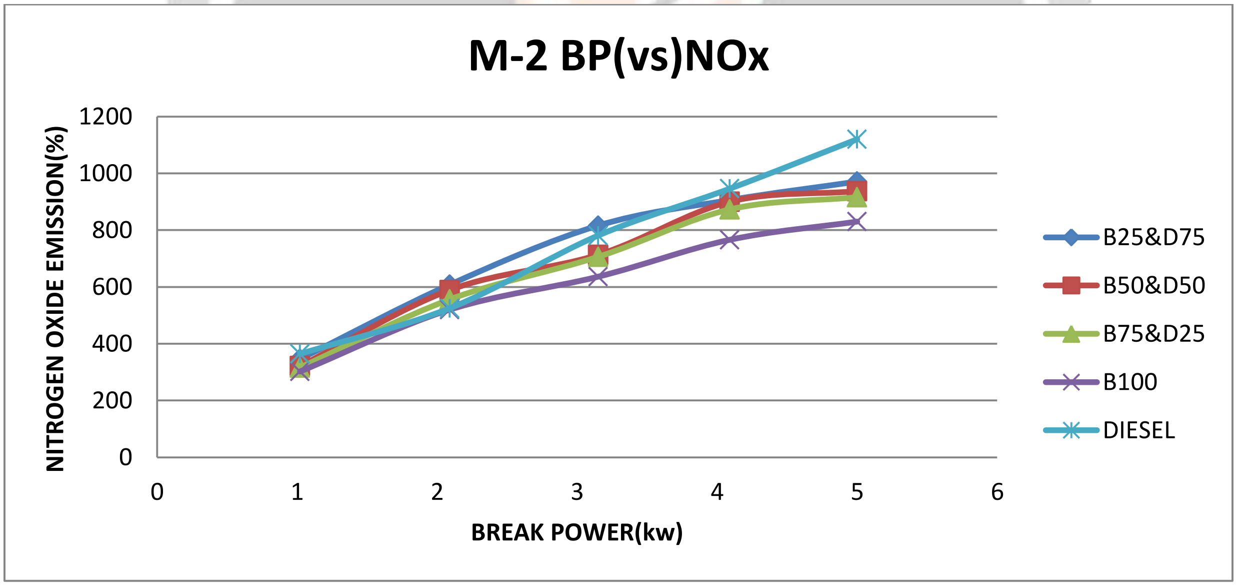

Chart-12: Modified piston

5.7Smoke density Vs BP:

The variation of smoke opacity with brake power for all the test fuels with both the piston operations . At all loads, smoke opacity for biodiesel decreased significantly than diesel fuel with base engine. This may be due to presence of oxygen in biodiesel and its blend. This oxygen in the fuel leads to an improvement in diffusive combustion. Smoke emissions were found lower for TCP than HCP, due to more complete combustion due to better air motion by the TCC resulting in better air-fuel mixing, leads to complete combustion. The smoke emission for B25,B50,B75 and B100 with TCC is 63%,64%,70% and 80%.whereas with HCP it is 65%,81%,84% and 90% respectively at full load.

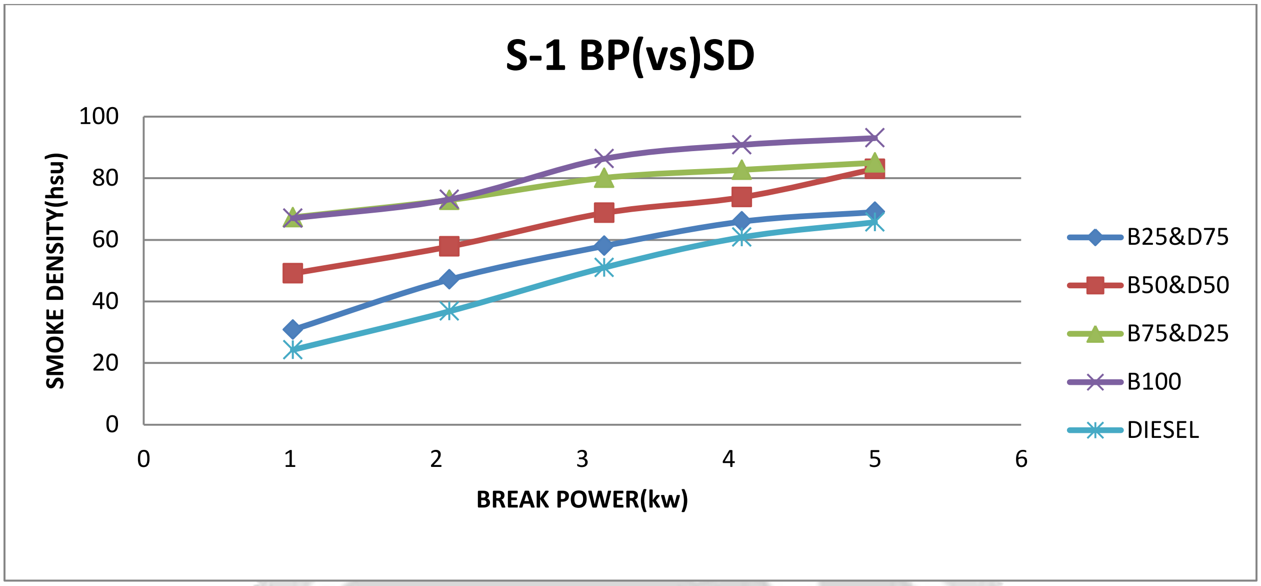

Chart-13: Normal piston

(VS)

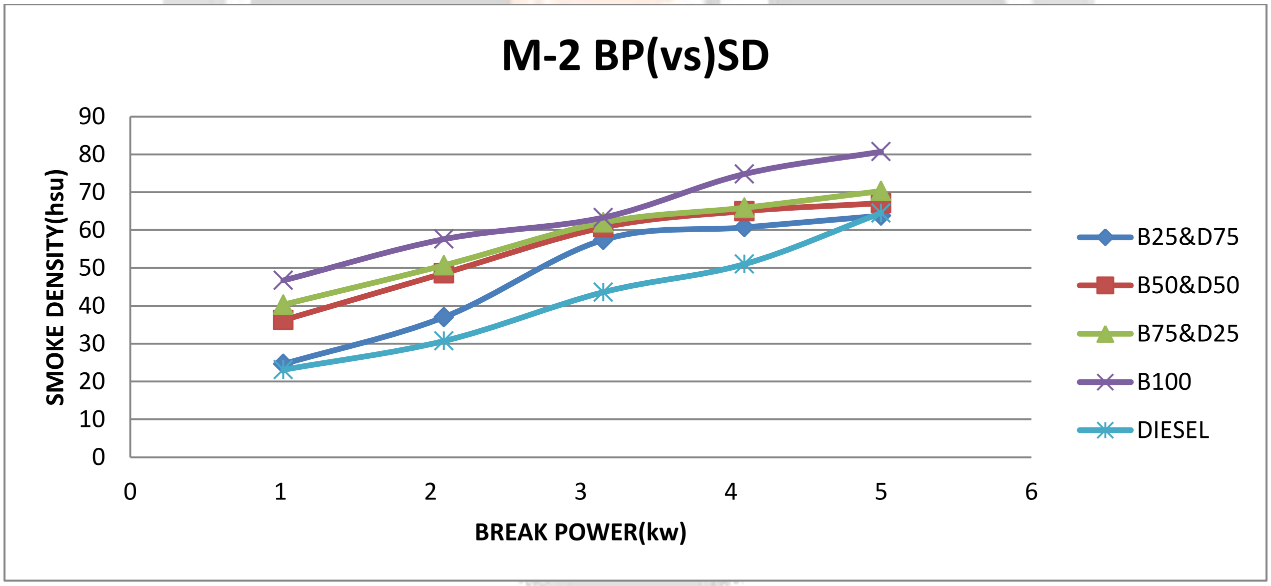

Chart-14: Modified piston

6.Conclusion:

When the present study effect of piston bowl geometries on emissions in a single cylinder diesel engine and performance emission test results of two configurations of the diesel engine are reported .Improved air motion in TCP due to its geometry improves mixture formation, which increases BTE and lowers BSFC compared to HCP. Better combustion due to better air fuel mixing in TCP, gives maximum thermal efficiency for B25.The CO, HC and smoke emissions were lower TCP with B25 due to improved air-fuel mixing and higher oxygen content present in COME and better combustion compared to HCP type combustion chamber. And litely decreses performances from B50 compare to B25 in TCP and also same for HCP . There are NO emissions were decreased for TCP due to better combustion and presence of oxygen content in COME results in increased combustion chamber compared with HCP type combustion chamber. Thus performance and emission characteristics of biodiesel from delonix regia and its blends can be improved by suitably designing the combustion chamber.

7.References:

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