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PerformanceAndEmissionCharacteristicsOfAVariableCompressionRatio Diesel Engine Using Methyl Esters Of Mustard Biodiesel Blends

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ABSTRACT
The use ofbiodiesel inconventional diesel engines resultsinsubstantialreductionof unburnedhydrocarbon,carbon monoxideand particulatematters. The performance, emission and characteristics of a single cylinder four stroke variable compression ratio multi fuel engine when fueled with mustard oil methyl ester and its 10%, 20%, and blends with diesel (on a volume basis) are investigated and compared with standard diesel. Bio diesel produced from mustard oil by transesterificationprocess has been used in this study. Experiment has been conducted a compressionratios of 14:1, 16:1and 18:1 The impact of compression ratio on fuel consumption, and exhaust gas emissions has been investigated and presented. Optimum compression ratio which gives best performance has been identified. The blends when used as fuel results in reduction of carbon monoxide, hydrocarbon and nitrogen oxides emissions. It is concluded that mustard oil ester can be used as fuel in diesel engine by blending it with diesel fuel.
Keywords—Variable compression ratio CI engine, performance, emissions, biodiesel, B10 (diesel 90% + Mustard oil 10% +0.05%Methyl-Ester) B20,diesel 80% + Mustard oil 10% + 0.10%Methyl-Ester)

I. INTRODUCTION

The world is currentlychallenged with the alikedisasters of fossil fuel reduction and ecologicaldeprivation. Haphazardmining and excessive consumption of vestige fuels have led to decrease in underground-based carbon resources. The search for alternative fuels, which potential a harmonious cor- relation with sustainable development, energy conservation, efficiency,and environmental conservation, has become very important today. Intensive research is going on throughout the world for a suitable diesel auxiliary. In this race amid different substitutes, vegetable oils have achievedkey place as some of their physical, chemical, and combustion related properties are nearly similar to those of diesel fuel. A lot of research work has been carried out to use vegetable oil in its neat form. Since India is net importer of vegetable oils, edible oils cannot be used for substitution of diesel fuel. So, mainattention has been focused on nonedible oils as the fuel alternative to diesel fuel .Many efforts have been made by several researchers to use nonedible oil as an alternative fuel in CI engine. Nonedible oil from the plant seeds is the most hopeful alternative fuel for CI engine, because it is renewable, environment friendly nontoxic, biodegradable, also has no sulphur and aromatics, and has favorable heating value and higher cetane number. Its chemical structure contains long chain saturated and unbranched hydrocarbons that are the most favorable property for the use in conventional diesel engine [1–6].

In this paper, to study the performance, and characteristics emission of a variable compression ratio four stroke diesel engine, coupled with a computer. The Blends used are the following: M10 (Mustards oil10%+Diesel 90%),M20(Mustardsoil20%+Diesel 80%,) at varying compression ratios of 14,16 and 18

II. LITERATURE SURVEY

Ramesh et al. [7] investigated the performance of a glow plug-assisted hot surface ignition engine - using methyl ester of rice bran oil as fuel. Normal and mnemonic crown pistons were used for their tests. They reported an improvement in brake thermal efficiency of about 1% when the glow plug is on. The percentage improvement in brake thermal efficiency was higher in the case of normal piston compared with that in the case of mnemonic piston.

Larry Wagner et al. [8] studied the effect of soybean oil esters on the performance and emissions of a four-cylinder direct-injection turbocharged diesel engine. They found that the engine performance with soybean oil esters is the same with diesel.

Clark et al. [9] studied the effect of methyl and ethyl esters of soybean oil on engine performance and durability in a direct-injection John Deere four-cylinder diesel engine. They observed that the engine-fuelled with soybean esters produced less- power output with an increase in fuel consumption. Emissions results were found to be similar to diesel.

Pan war et al. [10] conducted an experiment in single-cylinder variable compression ratio diesel engine at different loads. The engine performance for castor methyl ester was investigated. The lower blends of biodiesel increased break thermal efficiency and reduced fuel consumption.

The work done by Gumus et al. [11] deals with the performance and emissions of a compression-ignition diesel engine without any modification using neat apricot seed kernel oil methyl ester and its blends. They found that a lower concentration of apricot seed kernel oil methyl ester in blends gives better improvement in engine performance and exhaust emissions.

The work done by Celikten et al. [12] tells about the performance and emissions of diesel fuel from rapeseed and soybean oil methyl esters injected at different pressures (250, 300, and 350 bar), and they were compared. It has been found that the torque and power of diesel fuel engine were reduced with increasing injection pressure. Smoke level and CO emission were also reduced, while NOx emission was increased as the injection pressure was increased.

Jindal et al. [13] studied about the comparison of performance and emission characteristics for different compression ratios along with injection pressure, and the best possible combination for operating engine with Jatropha methyl ester has been found. It is found that the combined increase in compression ratio and injection pressure results in an increased brake thermal efficiency and reduced- brake specific fuel consumption while emissions were lowered. The combustion performance and ex- haust emission characteristics of turpentine oil fuel blended with conventional diesel fuel in a diesel engine was evaluated

In 2009, Arul MozhiSelvan et al. [14] compared the combustion characteristics of single-cylinder four-stroke direct injection variable compression ratio engine under compression ratios of 15:1, l7:1, and 19:1 when using diesel and bio diesel ethanol blends as fuel. It has been observed that the cylinder gas -pressure, maxi mum rate of pressure rise and heat release rate increase with higher ethanol concentration due to longer ignition delay. The exhaust gas temperature was found to be less. The study also examined the fuel burning characteristics of the diesel–bio diesel ethanol blends under various compression ratios and loading conditions. The performance and emission tests have been carried out - by using the stable fuel blends on a computerized variable compression ratio engine and compared with neat diesel

In 2010, Panwar et al. [15] investigated the engine performance of Castor Methyl Ester (CME) and Potassium Hydroxide (KOH) catalyst used infour-stroke, single cylinder variable compression ratio type diesel engine at different loads and concluded that the lower blends of bio diesel increased the break thermal efficiency and reduced the fuel consumption. The exhaust gas temperature increased with increasing bio diesel concentration

Gumus and Kasifoglu [16] studied the performance and emissions of a compression ignition diesel engine without any modification, using neat apricot seed kernel oil methyl ester and its blends with diesel fuel and found that lower concentration of apricot seed kernel oil methyl ester in blends give a better improvement in the engine performance and exhaust emissions

C.Solaimuthu, D.Senthilkumar [17] studied the diesel engine performance, combustion and emission characteristics mahua bio diesel (mahua oil methyl ester) and its blends in different volumetric proportions with diesel. They found that the brake thermal efficiency is almost same and less fuel consumption and also show that reduced NOX and HC emissions.

Saravanan et al. [18] analyzed the combustion characteristics of crude rice bran oil methyl ester blend in a direct injection compression ignition engine and found that the cylinder pressure was comparable whereas the delay period and the maximum rate of pressure rise were lower than that of diesel.

IsmetCelikten et al. [19] compared the performance and emissions of diesel fuel from rapeseed and soybean oil methyl esters injected at different pressures (250,300 and 350 bar). It has been found that the torque and power of diesel fuel engine reduced with increasing injection pressure. Smoke level (%) and CO emission also reduced while NOxemissionincreased as the injection pressure is increased

Jindal et al. [20] studied the effects of the engine design parameters such as compression ratio, fuel injection pressure and the performance parameters such as fuel consumption, brake thermal efficiency, emissions of CO, CO_2, HC, NOx, smoke opacity with Jatropha methyl ester as fuel. A comparison of performance and emission for different compression ratios along with injection pressure and the best possible combination for operating engine with Jatropha methyl ester has been found. It is found that the combined increase in compression ratio and injection pressure increases the brake thermal efficiency and reduces the brake specific fuel consumption while lowering the emissions

Raheman and Ghadge [21] studied the performance of Ricardo E6 engine using bio diesel obtained from mahua oil (B100) and its blend with high speed diesel at varying compression ratio, injection timing and engine loading. The brake specific fuel consumption and exhaust gas temperature increased, whereas brake thermal efficiency decreased with increase in the proportion of bio diesel in the blends for all compression ratios (18:1–20:1) and injection timings (35–45 before TDC). The authors concluded that, bio diesel could be safely blended with HSD up to 20% at any of the compression ratio and injection timing tested for getting fairly accurate performance as that of diesel

Most of the studies are conducted in different types of engines with bio diesel prepared from different oils. The effect of parameters on the performance of the engine with emission characteristics of the bio- diesel has been emphasized in many studies [22]. However,

properties	Must red oil	Bland10	Blend20	Diesel
Viscosity at 32∘ C, cSt	10.54	4.534	5.59	4.2
Densityat32 °C,g/cc	0.8802	0.8322	0.8382	0.86
Flash point (°C)	187	50	53	47
Fire point(°C)	207	67	71	64
Cetane index	50	54	52	55
Calorific valu (mj/kg)	39.45	43.12	42.68	45

it has to be noted that the study onvariable compression ratio engine using bio diesel is limited [14,18,21]. The effect of compression ratio on engine parameters, emission and combustion characteristics have not been studied extensively. Hence this study has been devoted to find suitable compression ratio which giveoptimum performance

III. Bio Diesel Production Process

The transesterificationreactionwascarriedout with 6:1molarratiomethanoland0.3%w/vKOHasan alkalinecatalyst.Themustardoilwaspreheatedto theset temperature60°Cona heatingplatepriorto startingthe reaction.Afixedamountoffreshly preparedmethanol solutionsof theselectedcatalystsKOH,wereaddedintothe reactor,andmixed.Thereaction wascarried outat 60°C for2h.The mixturewasallowedto settleovernightbefore removing theglycerollayerfrom thebottominaseparating funneltogettheesterlayeronthe top,separatedasbiodiesel.

Theobtainedpuremustardoilwasaddedto dieselfuel volumetricallytoobtainB10andB20 blends

1 The chemical formula for biodieselTransesterification is

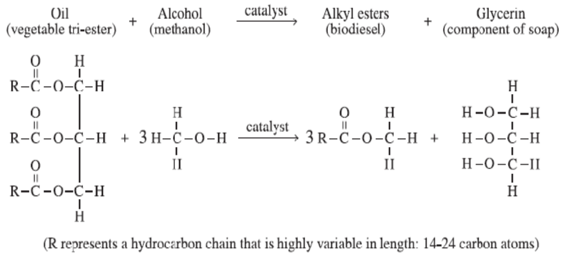

Fig 1:BasicTransesterification reaction [22]
Theprovidesasimplifieddiagramof thetransesterificationprocess.

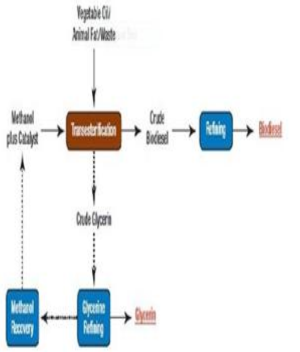

Fig.2BasicProcessofBioDiesel[22]
Fig.MustardOilBioDiesel withGlycerin.

2.PROPERTIES OF BIODIESEL COMPARISONWITH DIESEL
TABLE

IV. EXPERIMENTAL INVESTIGATION

In order to evaluate and compare the performances and emission characteristics of the fuel, the experiments were conducted using a VCR diesel engine in thermal laboratory. This section deals with description of the experimental set up, various instruments and software used for testing.

1. DESCRIPTION OF TEST RIG

A single cylinder,water cooled3.73kWpower,variablecompressionratioengine wasusedforthetestasshowninFigure1.Thistestbedhasaprovisiontochangeitscompressionratiobyrisingorloweringboreheadof the engine.Thetest bed isalso equippedwithall thecontrolelectrical,electroniccomputer,anddataacquisitionsystem.Forrunningtheengine,thecompressionratiooftheenginewaschangedtothedesiredratio.Enginewasstartedmanually.Loadingandunloadingweredonethroughcomputer.Varioussensorsaremountedontheenginetomeasuredifferentparameters.Atemperaturethermocouplewasinstalledonthesurfaceofhighpressurefuelpipe.Apreci sioncrankangleencoderwascoupledwiththemainshaftof theengine.k-typeofthermocouplesisplacedatdifferentpointstonotetheetemperaturesattheinlet,exhaustoftheengine,enginehead,coolingwaterinlet,coolingwateroutlet,andlubricating oiltemperatures.

Fig: 4 Schematic of Experimental Setup and Engine arrangement

2. TEST ENGINE SPECIFICATIONS

TABLE II
ENGINE DETAILS

Generaldetails	4-Stroke,watercooled,variable compression ratioengine,compressionignition
Ratedpower	3.7kW
Speed	1500rpm
Number ofcylinder	Singlecylinder
Compressionratio	12:1–20:1(variable)
Bore	80mm
Stroke	110mm
Ignition	Compressionignition
Loading	Eddycurrent dynamometer
Starting	Manualcrankstart

3. TEST METHODOLOGY

The present set ofexperiments were conducted on a four stroke single cylinder vertical water cooled diesel engine equipped with a computer. First the maximum torque of the engine is calculated and the engine is started under no load condition by hand cranking using de-compression lever. The engine will run under no load condition for a few minutes so that the speed stabilizes at rated value. Now by increasing the load from zero to maximum and setting the compression ratio 12 to 20 the respected values are automatically saved in a computer and also the exhaust emissions are noted down by using digital gas analyzer indicator. The two types of blends (B10, B20) were used in this experiment. The different parameters required for evaluation of fuel was noted.

V. RESULTSANDDISCUSSIONS

1. ENGINEPERFORMANCETESTANALYSIS

Engineperformance characteristics arethemajorcriterion that governs thesuitability ofafuel. The following engine performanceparametersareevaluated.

1.1 BRAKETHERMALEFFICIENCY

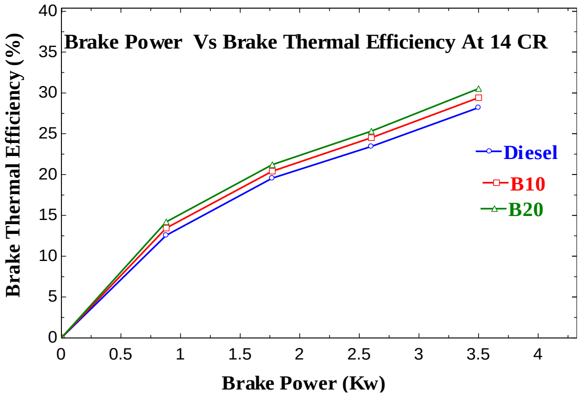

Fig: 5Variation of brake thermal efficiency for B10,B20its Blends and diesel at CR 14

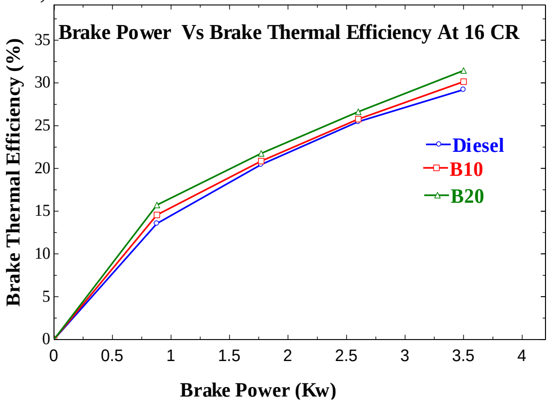

Fig: 6 Variation of brake thermal efficiency for B10, B20 Blends and diesel at CR 16

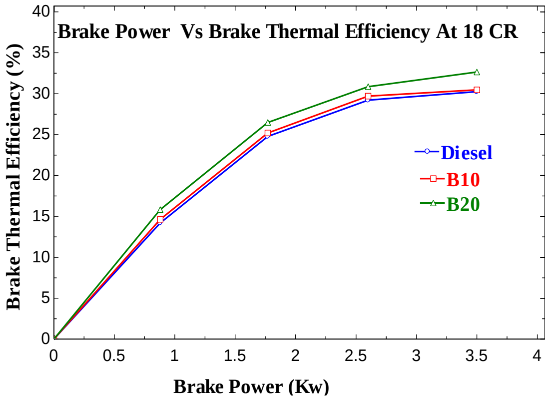

Fig: 7 Variation of brake thermal efficiency forB10, B20 Blends and diesel at CR 18

Thevariation ofbrake thermal efficiency withrespect to brakepowerforbothfuelsanditsblendsisas shownin Figs:5,6,7Brake thermal efficiency ofB10, B20 blends isslightly higherascomparedtothatofdiesel.Ithasbeenobservedthat thebrakethermalefficiencyof theblendsisincreasingwith increaseinappliedload.Itwashappeneddutoreductionin heatlossandincrease inpower developed withincrease in load.Themaximum brakethermalefficiency atfullloadis32.63%for B20atCR18whichis7-8%higherthan thatof diesel.Byincreasingthe loadof theengine,thebrake thermalefficiencyalsoincreasesforBlends B10, B20 compare tothed i e s e l fuel.

1.2RAKESPECIFICFUELCONSUMPTION

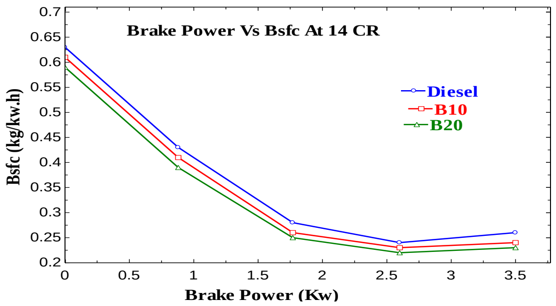

Fig:8Variation of brake specific fuel consumption for B10, B20 blends and diesel for CR 14

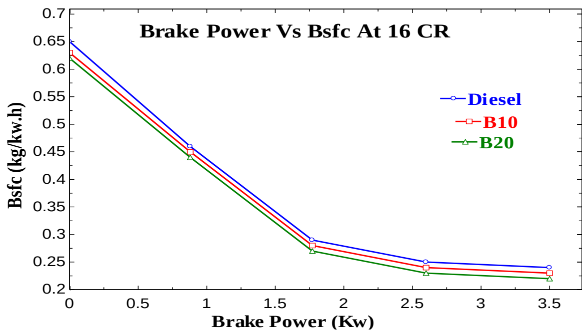

Fig:9 Variation of brake specific fuel consumption forB10, B20 blends and diesel for CR 16

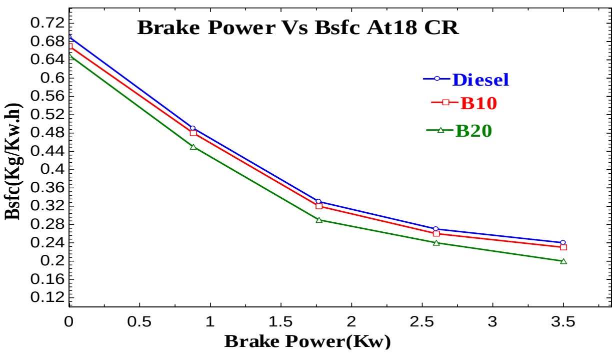

Fig:10VariationofbrakespecificfuelconsumptionforB10, B20blendsanddieselforCR18

Variation of brake specific fuel consumption with show in figs.8,9, 10 B10haslowercalorificvaluethanthatof diesel.Hencethespecificfuelconsumptionis slightlyhigher than that of diesel for ;and its blends. At higher percentageofblends,theSFCincreases.Thismaybedueto fueldensity,viscosityandheatingvalueof thefuels.B20has higherenergycontentthanotherblends,butlowerthandiesel.

1.2 MECHANICALEFFICIENCY

Thevariationofmechanicalefficiencywithrespecttoload forbothfuelsanditsblendsisas shown

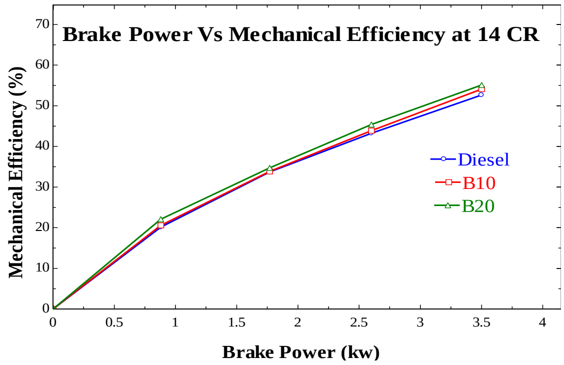

Fig:11 VariationofmechanicalefficiencyforMME,itsBlendsand dieselforCR14

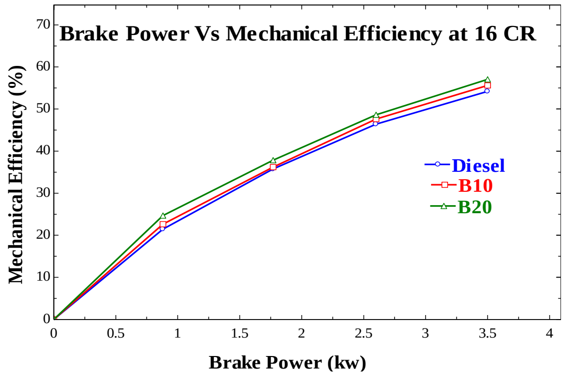

Fig:12 VariationofmechanicalefficiencyforB10, B20 Blendsand dieselforCR16

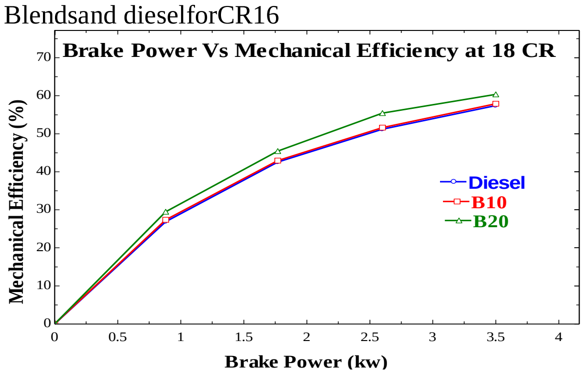

Fig: 13 Variationofmechanicalefficiencyfor B10,B20Blendsand dieselforCR18

In Figs: 11,12,13. The mechanicalefficiencyforB10,B20blendsare slightly increases compare todiesel for all compression ratios.The mechanical efficiency of the blendB20increases withtheincrease incompression ratio, whencomparedto thatofstandarddiesel.Themaximum mechanical efficiency obtained fromblend B20 for compressionratio18is 58.79%.Mechanicalefficiency increaseswithincreasingcompressionratioforalltheblends

1.3 EXHAUSTGASTEMPERATURE

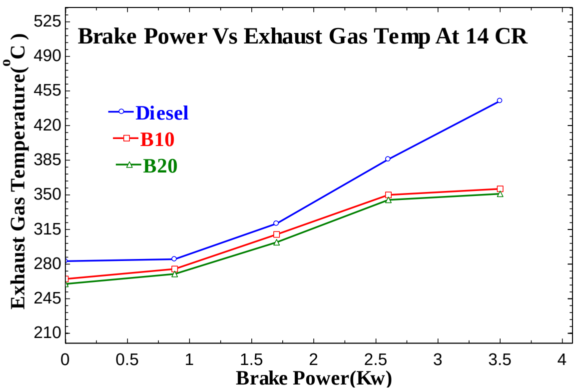

Fig: 14 Variation of exhaust gas temperature for B10, B20 Blends and diesel for CR 14

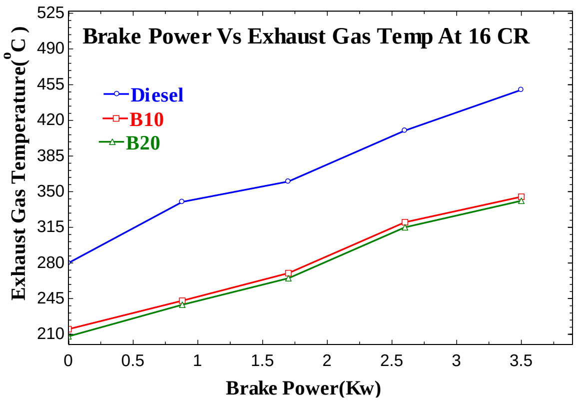

Fig: 15 Variation of exhaust gas temperature for B10, B20 Blends and diesel for CR 16

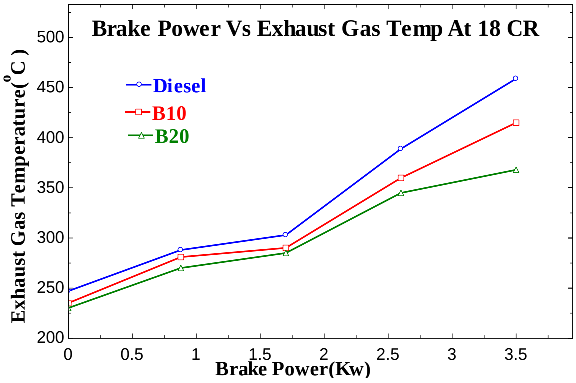

Fig: 16 Variation of exhaust gas temperature for B10,B20 Blends and diesel for CR 18

Thevariationsof exhaustgastemperaturefordifferent compressionratioandfordifferentblendsareshownin Fig.14,15,16. The resultindicatesthat exhaustgas temperaturedecreasesfor different blends when compared tothatofdiesel. Atmediumcompression ratio16:1theexhaustgastemperature ofthe blendsarelowercomparedtothatof standarddiesel.Asthe compression ratio increases, theexhaust gastemperature of thevariousblendsislesserthanthatofdiesel because we are adding (MTB) methyl tetra butyl ether to blends.Thehighest temperatureobtainedis 459^{0}Cforstandarddiesel.Fora compressionratioof16:1 where asthetemperatureisonly341^{0}CfortheblendB20.

2 ENGINEEMISSIONPARAMETERS

Withproblemlikeglobalwarming, ozonelayerdepletion and photochemical smog in addition to widespread air pollution, automotive emission are placed under the microscopeandeverypossiblemethodisattemptedto reduce emission. Following EngineEmission parameters are evaluatedforB10,B20blendswithdiesel.

2.1 CARBONMONOXIDE

The variation of carbon monoxide with respect to brake power for both blends and dieselisasshown inFig. 17,18,19. Carbonmonoxideemissionsaredecreases with increase in blend percentage at compression ratios 14,16cr.At all blinds COis gradually decreased because CO is converted to CO2duetothepresenceof oxygen in biodiesel.Sincemustard biodiesel isan oxygenatedfuel,it leadstobettercombustionoffuelresultinginthedecreasein COemission.

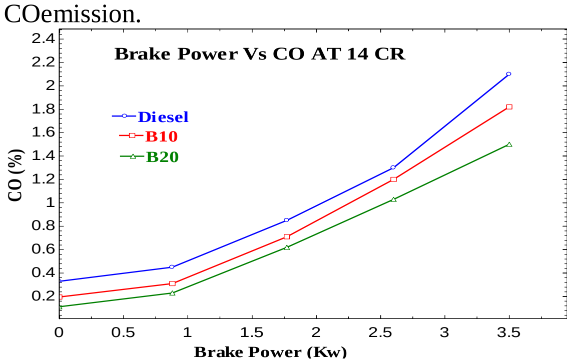

Fig:17VariationofcarbonmonoxideforB10,B20Blends anddiesel forCR14

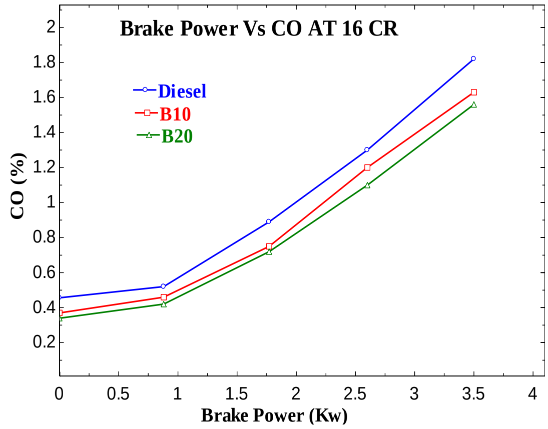

Fig:18Variationofcarbonmonoxidefor B10, B20Blendsanddiesel forCR16

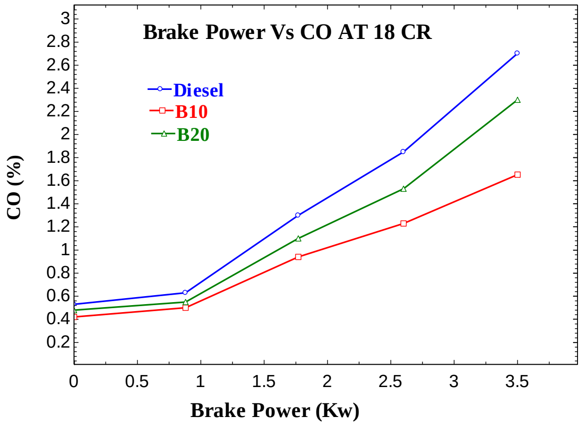

Fig:19Variationofcarbonmonoxidefor B10, B20Blendsanddiesel forCR18

TheCOemissionoftheblendB10,B20islessthan thestandarddiesel. Andit isfoundto bethe blend B20 moderatecompression ratio16 CO emission is1.5(%) is lesser for all compression ratios .

2.2 HYDROCARBONS

Thevariationof hydrocarbonswithrespectto loadforboth fuels and blends is as shownin Fig. 20,21,22. HC emissions reduceddrastically at all blends at all compression ratios.

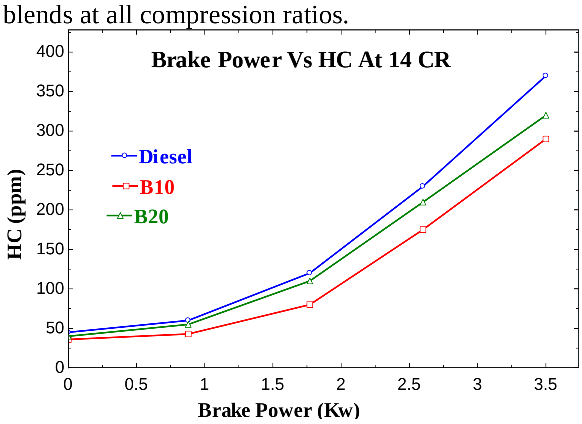

Fig:20VariationofHydrocarbonsforblendsanddieself or CR14

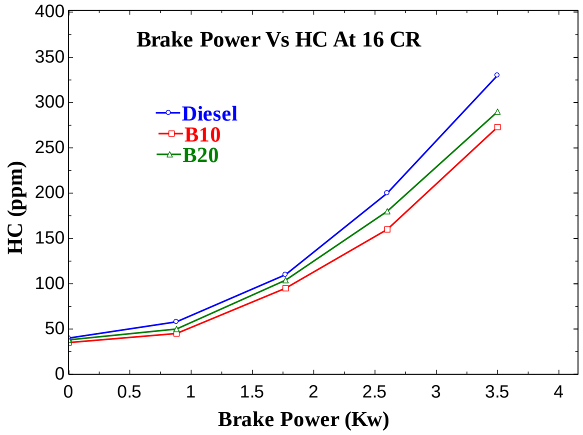

Fig:21VariationofHydrocarbonsforblendsanddiesel for CR16

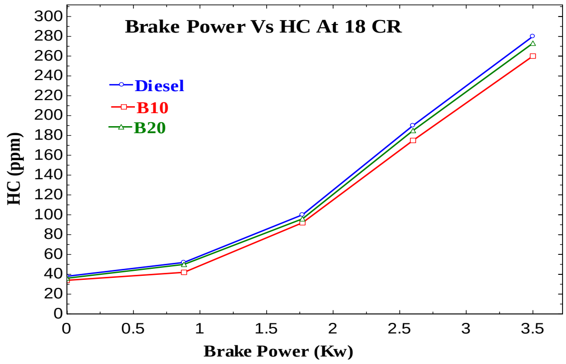

Fig:22VariationofHydrocarbonsforblendsanddiese lfor CR18

Theblendsproducelesserhydrocarbonemissions ata l l compression ratiothanthestandarddiesel.Dueto theshorterignitiondelay,the complete combustiontakes place in combustion chamber.

2.3 NITROGENOXIDE

The variation of nitrogen oxide with respect to load for both fuels and its blends is as shown in Figs: 23,24,25.NOxdrastically decrease with the increase in percentage of blends in the fuel at 14,16 cr. The NOxdecrease because we are MTB additiveit having anti knocking charactreristics.TheNOx emissions for all blends decreasedcompared to diesel because of the exhaust gas temperatures of all blends decrease compared diesel. Among these blend 10 at14cr is lower in NOx.

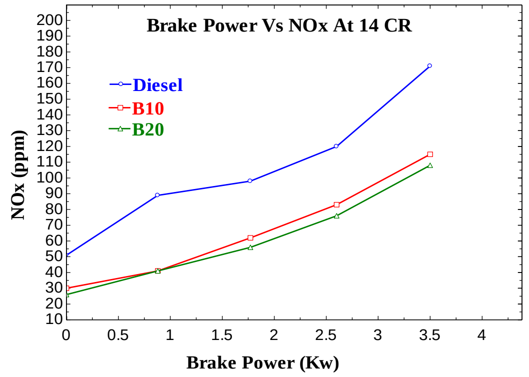

Fig: 3Variationofnitrogenoxideforblendsanddieselfor CR14

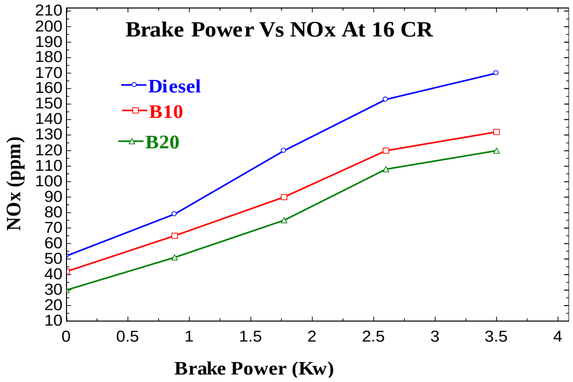

Fig:24Variationofnitrogenoxideforblendsanddieself or CR16

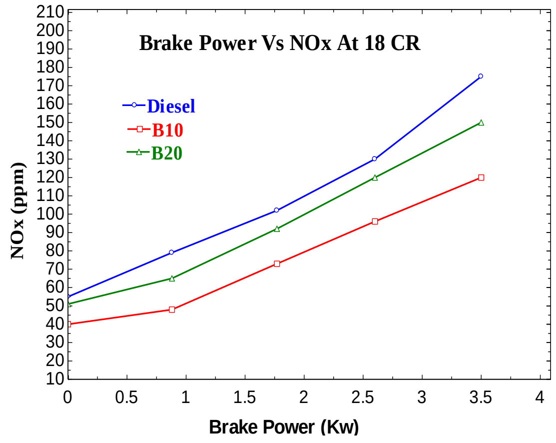

Fig: 25Variationofnitrogenoxideforblendsanddieselfor CR18

VI. CONCLUSION

Theperformance, emissionandcombustioncharacteristics of a variablecompressionratioenginefueledwithmuatardbiodiesel and diesel blends have been investigated and compared with that of standard diesel. The experimental results confirm that the BTE, SFC, exhaust gas temperature and mechanical efficiency of variable compressionratioengine,areafunctionofbiodieselblend , load and compression ratio. For the similar operating conditions,engineperformanceincrease with increasein biodieselpercentagein theblend.Howeverbyincreasingthe compression ratio the engine performance varied and it becomescomparable withthatof standarddiesel.The performanceand emission characteristics of a singlecylinder directinjection CIengine fuelled withB10,B20blendshavebeenanalyzedandcomparedto thebase linedieselfuel.Thefollowingconclusionsare drawnfromthis investigation

- The specific fuel consumption decreasewith increase in percentage of the blends due to the addation of MTB addative to mustard biodiesel.
- Methyl ester of mustard oil results in a slightly increased thermal efficiency as compared to that of diesel at higher compression ratio.
- The exhaust gas temperature decreases at higher compression ratio. The reason is the lower calorific value of blended fuel as compared to that of standard diesel and lower temperature at the end of compression. The exhaust gas temperature for the blend 20 is lower compared to that of standard diesel at lower compression ratios.
- The brake thermal efficiency of the blend B20 is slightly higher than that of standard diesel at higher compression ratios. The specific fuel-consumptionof blend B20 is lower than that of all other blends and diesel. This may be due to better combustion, and increase in the energy content of the blend.
- The hydrocarbon emission of various blends is higher at higher compression ratios. The increase in compression ratio increases the HC emission for blend B40. CO emission is low at higher loads for methyl ester of mustard oil when compared with diesel. NOx emission is decreased with methyl ester ofmustrad oil compared to diesel.
- Mustards biodiesel satisfies the important fuel properties as per ASTM specification of biodiesel and improves the performance, combustion and emission characteristics of engine significantly.

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