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Experimental Investigation of NOx Reduction in Biodiesel Blends

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Abstract
Rapid increase in the rate of fossil fuel depletion has raised concerns all over the world. People are starting to use alternative renewable fuels along with the fossil fuels. One of the largely used alternative fuels is the biodiesel, which can be used directly along with the diesel without making much modification to the engine. The commonly observed disadvantages while using biodiesel- diesel blends are increased emission. The aim of this work is to study the effect of adding nanoparticles in a biodiesel- diesel blend on the performance and emission attributes of a diesel engine. Biodiesel obtained from orange peel, corn, mustard, neem, mahua, cashew nut shell oil is used in this paper. It is observed that the fuel consumption and emissions such as NO, CO and smoke are decreased for these blends.

Keywords: *EMISSION, BIODIESEL, FUELS, ADDITIVES, DIESEL ENGINE*

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I. INTRODUCTION

The economy of any country is advanced by the operationalization of a better transportation system as the average consumption of energy by the transport sector increases 1.1% per year. The industrialization has led to an increase in energy consumption and demand. In the early stages to meet the energy demand crude oil was used as an alternative, and the world faced a shortage of crude oil from 1970. To resolve this issue, researchers and scientists around the world effectuated the research on developing alternative fuels. The population growth has led to the increased usage of automobiles resulting in the increase of harmful emission gases to the earth's atmosphere. Biodiesel combustion curtails the emission gases such as carbon monoxide, sulphur dioxide, unburned hydrocarbon, and nitrogen oxides, compared to conventional diesel fuel. Many researchers have reported that biodiesel and traditional diesel have indistinguishable physical and chemical properties. The use of biodiesel had an increasing trend because of its compatibility with a diesel engine without any modifications.To study theInfluence of water on Orange peel oil and Corn oil biodiesel, Effect ofoxygenated additive on mustard biodiesel, Effect of higher alcohol in Neembiodiesel, Role of nano additives (CNT &CeO_2) on Neem biodiesel, CeO_2 on Mahua oil and ZnO on Cashew nut shell oil Effect of preheating the Cashew nut shell oil biodiesel on Emission

VEGETABLE OIL BIODIESEL

Table 1: *Fuel Samples*

DIESEL				
BIO DIESEL	Orange Peel Oil Biodiesel	BD100	BD95W5	BD90W10
	Corn Oil Biodiesel	COBD	COBDE1	COBDE2
	Mustard Biodiesel	B100	BD90DTBP10	BD80DTBP20
	Neem Biodiesel	NBD	NBD + 50ppm CNT	NBD+100ppm CNT
		NBD	NBD+10nmCeO_2	NBD+20nmCeO_2
		NBD	NBD90A10	NBD80A20
	Mahua oil biodiesel	MOBD	MOBD$CeO_2$100	MOBDCeO2200
	Cashew nut shell oil biodiesel	BD100	BD100T70	BD100T80, BD100T90
		BD100	BD100ZnO10 (10nm)	BD100ZnO2 (20nm)

Orange peel oil biodiesel:

Materials andMethods of Test FuelPreparation:
Oil is extracted from orange peels by Steam distillationprocess
AdditivesWater 5% , Biodiesel 95%, Water10%, Biodiesel90%, Neat Biodiesel100%
Diesel
ExperimentalSetup:
Engine – Common rail, 1 cylinder and Direct Injectiondieselengine (Power 4.2kw and 1300rpm
Test FuelPreparation:

- Orange peel oil – extraction by steam distillationprocess
- 1.2 kg of Orange peels are placed in the steam chamber and heated to 110°C
- Orange peel oil was separated from the mixture due to its density difference
- 1.2 kg of orange peel yielded 700 ml ofoil
- 600 gm sample of oil in the reactor was heated to75°C

Transesterificationprocess:

- Molar ratio is 6:1 (methanol tooil)
- Catalysts 0.25% (wt/wt) tobiodiesel
- Orange oil biodiesel isseparated
- Properties of test fuels estimated according to ASTMstandards

Results andDiscussion:
Carbon MonoxideEmission:

  - CO emission (from BD100,BD95W5,BD90W10) is comparatively lower that ofdiesel
  - Availability of Oxygen in blends of biodiesel andwater
  - Accelerates oxidationreaction
  - Reduces COemission
  - CO emission decreases with increase in water content forbiodiesel
  - CO emission – 8.8% lower for BD95W5 and 11.16% lower for BD90W10 as compared toBD100
- Low viscosity of BD95W5 of BD90W10 boosts evaporation and reduce COemission

Unburned HydrocarbonEmission:

  - HC emission formedby
  - excess assimilation of air andfuel
  - Poor mixing of fuel injection at the end of combustionprocess
  - Fuel impingement on the combustion chamberwalls

HC emission for BD95W5, BD90W10 and BD100 is lower than that of diesel at all

- Brakepower
- BD95W5, BD90W10 and BD100 contain lower carbon atom and enriched oxygen – promotes combustion and lower HCemission
- Addition of water (in BD95W5, BD90W10) has reduced the unburned hydrocarbon emission

Oxides of NitrogenEmission:

- Depends on oxygen content and the mass of fuelburned
- NOx emissions from BD95W5, BD90W10 and BD100 are higher than that ofdiesel
- Higher emission due to rich availability of oxygen in blends of biodiesel andwater
- Inherent oxygen content in BD95W5, BD90W10 and BD100 accelerates the oxidation reaction and increaseNOx
- Emission for BD95W5, BD90W10 is inferior than that of BD100 at allconditions
- Water particle in BD95W5 and BD90W10 reduces the gas combustion temperature and lower NOxemission

SmokeOpacity:

- Smoke emission is lower than that of diesel at all brakepower
- BD95W5, BD90W10 and BD100 contains lower carbon atom and enriched oxygen (promotes the combustion and lower smokeemissions)
- Addition of water to bio diesel reducessmoke
- Water concentration increases evaporation and result in over smoke emission for BD95W5, BD90W10 andBD100

Conclusion:

  - Neat fuel shall be used as a neat fuel in an unmodified dieselengine

BD95W5 and BD90W10 exhibit lower HC andCO
Maximum reduction of 8.8% of HC and 10.1% of COobtained
Presence ofwater
Increases evaporationtendency
Resulted in completecombustion
Lesser HC and COemission
NOx and smoke emission reduced largely forBD90W10
Maximum reduction 12.4% of NOx and 18.4 % of smoke emission for BD90W10 (as compared toBD100)
Water particle helps to reduce the peak temperature insidethecylinder by absorbing the heat energy during the combustion

Corn oil biodiesel
Materials andMethods:
Test FuelPreparation:
Edible Corn Oil is converted to biodiesel bytransesterification process
Additives -water
EmulsionPreparation:
Emulsion is prepared by changing the proportion of surfactants andwater
ExperimentalSetup:
Engine – Water cooled naturally aspiratedstationaryapplicationdieselengine
(Power4.2kW)
Results and Discussion:
Brake Thermal Efficiency:
BTE is lower than diesel owing to its lower heatingvalue
BTE (of COBD, COBDE1, COBDE2) is lower than diesel owing to its lower heatingvalue
BTE (of COBDE1, COBDE2) is higher than COBD at all testingconditionsWatercontentinCOBDE1andCOBDE2 conversiontosuperheatedsteamandproducesmorepower (increasesfuelefficiencyatallengine loads)
This is because of the heat sink effect of water present in thebiodiesel
Fuel with lower viscosity (COBDE1 and COBDE2) assist the combustion process as it combines the fuel with air and produces higherBTE.
Brake-Specific FuelConsumption:
BSFC reduces with BMEP for all tested fuel samples
BSFC of diesel was lower than that of other test fuels (COBDE1, COBDE2)
BSFC for COBDE1 and COBDE2was lower than neat COBD.
PrimaryreasonforthebehaviorisduetowatercontentinCOBDE1andCOBDE2which converts into super heated steam and produces more power,
thus reducing the fuel consumption rate
Fuel with lower viscosity (COBDE1 and COBDE2) assists the combustion process as it combines the fuel with air and produces lower BSFC
COEmission:
CO emissions are Comparatively lesser than that ofdiesel
CO emissions are Comparatively lesser than that ofdiesel
Abundant availability of inbuilt oxygen in COBD and waterblends
Inherent Oxygen content of COBD and water blends also accelerates the oxidation reaction and reduces the COemission
CO emission decreases with the increase in water content for cornbiodiesel.
CO emission for COBDE1 is 7.2% lower and for COBDE2was 9.6% lower than that ofCOBD
Low viscosity of COBD and water blends promotes evaporation process and decrease COemission.
Fuel with lower viscosity aids in better evaporation of fuel with air (results in improved combustion and lower COemission)
Unburned HCEmission:
HC emissions for neat COBD and its water blendss are lower than that of diesel atBMEP
Formation of unburned HC in a diesel engine is due to flammability region during the ignition delay period, poor mixing of fuel injection
at the end of the combustion process and fuel impingement on the combustion chamber walls.
HC emission for neat COBD and its water blends are lower than those of diesel at BMEP
The inherent oxygen content of neat COBD and water blends promotes the combustion process and lower HC

emissions
The addition of water into COBD (COBDE1 and COBDE2) reduces the unburned HC
emissions
The presence of water particles in the biodiesel accelerates the heat sink which in turn lowers the HC emission during emulsified fuel operation
Water in biodiesel increases the evaporation process and results in complete combustion and low HC emission
NOx Emissions:
NOx emissions from COBD and its water blends are higher than that of diesel at all
Conditions
Smoke Opacity
BSFC reduces with BMEP for all tested fuel samples.
BSFC of diesel was lower than that of other test fuels (COBDE1,COBDE2)
Conclusion:
Inclusion of water particles at different proportions to orangepeeloil biodiesel and emission parameters is studied
BTE of COBD is 25.1% COBDE1 is 26.4 % COBDE2 is 26.8anddiesel fuelis29%
BSFC of COBDE1 and COBDE2 is reduced with addition of water to the biodiesel
COBDE1 and COBDE2 exhibit lower HC and CO emission (ascompared to COBD)
Maximum reduction - 7.2% of HC and 9.6% of COemission
Water increases evaporation tendency resulting in completecombustion
NOx and smoke emission of the biofuel are largely reduced forCOBDE2(ascomparedtoCOBD)
Maximum reduction – 6.6 % of NOx and 4.2 % of smokeemission
Water in biodiesel reduces the temperature of combustion and absorbs heat energy duringcombustion

Mustard biodiesel
Materials andMethods
Properties of testfuel:
The properties of BD90DTBP10,BD80DTBP20,B100 and diesel are evaluated as per ASTMD6751.
Addition of DTBP to biodiesel reduces viscosity by13.2%
Cetane index of biodiesel is higher than that of biofuels due to its shorter chain length
Density of B100 is 5.7% higher than diesel due to its weight and molecular structure
The calorific value of B100 is 9.5% lower than diesel
Experimental set-up (engine testing)
A water-cooled and naturally aspirated stationary application diesel engine ofrated power 4.2 kW was subjected to emission testing.
Pollution from the exhaust tailpipe were measured using AVL di-gas gas analyzer and smoke was measured using AVL smokemeter in BSU
Comparison of emission parameters was conducted using neat biodiesel (B100), BD90DTBP10 and BD80DTBP20 with the baseline
operation of the engine i.e. withneat diesel.
Overall uncertainty = {(uncertainty of CO)2+(uncertainty of NOx)2+(uncertainty of HC)2+(uncertainty of Smoke)2+(uncertaintyof BTE)2
+(uncertainty ofBSFC)2}
= {(0.54)2+(0.61)2+(0.44)2+(0.58)2+(0.34)2+(0.55)2}
Results and Discussion:
Carbon Monoxideemissions:
BD90DTBP10, BD80DTBP20,B100 produces 4.14%,6.26%and 3.55% respectively
Lower CO emissions than thediesel
The DTBP addition with B100 lowers the COemission
CO emission reduce linearly with increase in proportion of DTBP.
The possible reason – lower chain of carbon atoms in its structure and improved ignition quality of DTBP inmodified fuels.
The oxygen content of BD90DTBP10, BD80DTBP20resulted in the reduction of COemissions
The maximum CO emission for diesel was 3.0 g/kWh, 2.8 g/kWh for B100,2.6 g/kWh for BD90DTBP10,2.3 g/kWhfor BD80DTBP20,
at maximum BMEP (6bar)
Unburnt hydrocarbon emissions:
HC emissions increase for all test fuels withBMEP
HC emissions for biofuels are lower than diesel at allBMEP.

The oxygen content of BD90DTBP10, BD80DTBP20, B100 leads to complete combustion, and hence BD90DTBP10, BD80DTBP20,
B100 produces 6.19%, 8.97%, and 4.41 % lower emission thandiesel
The DTBP addition with B100 reduces the HC emission significantly.
The maximum HC emission for diesel was 0.44 g/kWh, 0.38 g/kWh for B100, 0.44 g/kWh for BD90DTBP10, 0.44 g/kWh for BD80DTBP20
at maximum brake mean effective pressure (6 bar) .
Smokeemission:
Smoke emissions increase with BMEP for all testfuels.
Smoke emissions for BD90DTBP10,BD80DTBP20 and B100 are lower than the diesel
at allBMEP
BD90DTBP10,BD80DTBP20 and B100 produce 6.14%,8.1%,and5.41%
lower smoke emission than the diesel (at peak load condition)
The DTBP addition with B100 lowers the smokeemission
Smoke emission reduce linearly with increase in proportion ofDTBP
BD90DTBP10,BD80DTBP20, produces prolonged flammability and increases the combustion rate and reducetheDTBP blends in B100 reduce
the viscosity and cause higher dissipation, rapid and richer fuel-air blending and lower smokeemission.
The maximum smoke emission for diesel was 1.25 BSU, 1.1 BSU forB100,
0.9BSUforBD90DTBP10,0.8BSUforBD80DTBP,atmaximumbrake meaneffectivepressure(6bar)
Brake thermal efficiency:
BTE increase with BMEP for all testfuels.
Biofuels have lower calorificvalues
The calorific value of B100 is 9.5% lower thandiesel.
Hence more quantity of fuel is supplied to meet constant poweroutput
B100 produces 2.1% lower BTE than diesel fuel at peak loadcondition
The DTBP addition with B100 further lowersBTE
BTE reduce with increase in proportion ofDTBP
BD90DTBP10 and BD80DTBP20 produce 4.2 % and 4.8% lower BTE than the diesel fuel at peak loadcondition
The requirements of BD90DTBP10 and BD80DTBP20 for delivering the same power as that of diesel would be higher thereby causing heat losses
and paving way for lowerefficiencies
The maximum BTE for diesel was 28.8%, B100 is 26.8%, BD90DTBP10is24.6%andBD80DTBP20is24.1%atmaximumBMEP(6bar)
Brake specific fuel consumption(BSFC):
BSFC is a parameter, which defines fuel consumptionand utilization per unit power andtime
BSFCforBD90DTBP10, BD80DTBP20 and B100higherthan diesel at all BMEP.
BD90DTBP10,BD80DTBP20 and B100 produces 0.056 kg/kWh, 0.049 kg/kWh and 0.027 kg/kWh higher BSFCthan diesel fuel at peakcondition
The DTBP addition with B100 increases the fuelconsumption
BTE and BSFC are inverselyproportional
The maximum BSFC for diesel was 0.254kg/kWh, 0.281 kg/kWh for B100, 0.31 kg/kWh for BD90DTBP10 and0.33 kg/kWh for BD80DTBP20
at maximum BMEP (6bar)
Nitrogen oxideemissions:

Nox emissions for biofuels are higher than diesel at all BMEP
The DTBP addition with B100 lowers the Noxemission
Nox emission reduce linearly with increase in proportion ofDTBP
The maximum NOx emission for diesel was 13.1g/kWh,14.9g/kWhforB100,14.2g/kWh
forBD90DTBP10,13.4g/kWhforBD80DTBP20,atmaximumbrakemean effective
pressure(6bar)
Conclusions:
Fuel samples – BD100, BD90DTBP10,BD80DTBP20, anddiesel
DTBP – Oxygenatedadditive
Emission characteristics of the test fuelsanalysed
Production of Biodiesel – by Base – Catalysed transesterificationprocess
HC and CO emissions reduced with addition of DTBP as compared to BD100 (owing to enriched

oxygencontent)
Reduction in emission For BD80DTBP20 – 5.2 % in HC and 7.4 % inCO
Smoke opacity – reduced by 3.6% for BD80DTBP20 (due to enhancedspray
characteristics of DTBP blends)
NOx emission lowered by 6.86% for BD90DTBP10 and 11.2% for BD80DTBP20 than BD100. NOx emission for biodiesel is higher than diesel at allconditions
BTE in Ascending order: Diesel>B100> BD90DTBP10>BD80DTBP20 (owingto lesser calorificvalue)
Overall BSFC is: 1.63 kg/kWh (BD80DTBP20) , 1.55 kg/kWh (BD90DTBP10),and
1.44g/kWhB100)areinferiorto1.33g/kWh(Diesel)–owingtolessercalorificvalue

Neem biodiesel
Neem Biodiesel NBD Blending with Carbon NanotubesCNT
NBDCNT50 – CNT (alpha, 98+%)50ppm
NBDCNT100 – CNT (alpha, 98+%)100ppm
Materials and Methods:
Fuel Preparation-base catalysed transesterification process
CNT-procured from sigma-aldrich(99.4%)
Particle size 50nm.
Fuel containing CNT nanoparticle is also stirred using magnetic agitator for 60 min at a speed
of450 rpm
Engine setup-Single cylinder and four- stroke diesel engine
Results and Discussion:
Nitrogen Oxidesemission:
The NBD and CNT blends exhibit more amount of Nox than diesel due to higher oxygen availability that resulted in high combustion temperature and higher Noxemissions
Hydrocarbonemission:
The samples exhibit lower HC emissions than diesel at allloads
Carbon MonoxideEmission:
CO emission characteristics of the diesel are higher than that ofsamples
Carbon di oxideemission:
The amount of oxygen available in samples for combustion is adequate causing effective combustion and higher CO2 emissions thandiesel
Smokeopacity:
Smoke emissions of diesel are higher than that of allsamples
Conclusion:
Engine – single cylindertype
Fuel samples – NBD, NBDCNT50, NBDCNT100 anddiesel
CNT – metal basedadditive
Emission characteristics of test fuels have been analysedby comparing with the neat baseline dieselfuel
Production of biodiesel by base – catalysed transesterificationtechnique
Physiochemical properties of Biodiesel is par with ASTMstandards
NBD emits 4.8% higher NOx compared to diesel at peak loadcondition
CNT nanoparticle inclusion at 100 ppm promotes 9.2% lower NOx compared toNBD
Overall HC and CO emissions are 6.8% and 4.7% lower for NBD compared to diesel. CNT addition at 100 ppm further reduces the HC and CO emission by 6.7% and 5.9%respectively, compared toNBD
CO2 emission in NBD is 6.6 % higher than diesel at peak condition. The CNT inclusion with NBD further increases the CO2 emission due to completecombustion
Smoke emission of NBD is 2.1% lower than diesel at peakcondition.
The CNT inclusion at different ppm further reduces its smoke emissions by 7.8%when
compared to NBD
No provisions were provided to remove the nanoparticle after the combustion from the exhaust system.

Mahua oil biodiesel:
FuelPreparation:
MOBD is derived by transesterificationprocess
Preparation of CeO_2nanoparticles
By adding 100 and 200 ppm of TiO_2nanopowder to distilled water on volumebasisMixing CeO_2nanoparticles with MOBD using magnetic stirrer for 60 min at a speed of 510 rpm in atmosphericconditions
Notation:

$MOBDCeO_2100$ = MOBD + 100 ppmCeO_2
$MOBDCeO_2200$ = MOBD + 200 ppm CeO_2
Results andDiscussion:
NOxEmission:
Higher in MOBD and nanoparticleblends
Lower inDiesel
Causes:
Higher inbuilt oxygen in fuel
High temperature during combustion
CeO_2nanoparticle:
Catalytic effect promotes combustion by reducing ignition delay period
enhance the oxidation reaction during combustion
Reduce NOx emission
COEmission:
lower in MOBD and nanoparticleblends
higher in Diesel
Causes
SurplusO_2presentinMOBD,$MOBDCeO_2100$and$MOBDCeO_2200$ takeparting combustion
$MOBDCeO_2100$and$MOBDCeO_2200$showsignificantreductioninCOemissionthanneatbiodiesel
Improve d rate of Oxygen by donatingO_2
CeO_2nanoparticle
enhance the oxidation reaction during combustion
Reduce CO emission
SmokeEmission:
CeO_2nanoparticle
Reduce smoke emission
Causes:
Higher inbuilt oxygen molecules in fuels
Enhance the rate of evaporation of fuel with excess air
Reduce activation temperature of carbonaids completecombustionLower smoke emission
HCEmission:
lower in MOBD and nanoparticleblends
higher inDiesel
Causes:
Higher inbuilt oxygen
SurplusO_2presentinMOBD,$MOBDCeO_2100$and$MOBDCeO_2200$takeparting combustion
CeO_2nanoparticle:
ImprovetherateofcombustionbydonatingO2molecules
Enhance the oxidation reaction during combustion
ReduceCOemission
Conclusion:
Mahua Oil Biodiesel blended with CeO_2nanoparticles(100 ppm, 200ppm). Tested in diesel engine (1800 rpm constant speed) at
varying loadingconditionsCeO_2 reduce (HC, CO, NOx) Emissionssignificantly. Biodiesel with 200 ppm of CeO_2achieved.
Significant reductions in all the emissions
Causes
Catalytic effect
` Improved thermal conductivity
BetteroxidationcapabilityofCeO_2nanoparticles

Cashew nut shell oil biodiesel
Properties of Biodiesel-Cashew Nut Shell oilCNSL:
Reddish brown
Viscousliquid
Cashew nut shellconstituents
Epicarp

Endocarp
Mesocarp
Natural resin which contains theoil
Cashew nut-edible
CNSL- oil between seed coat and thenut
Results and Discussion:
CO Emission:
CO emission from biodiesels are lower than diesel at all loads
Higher oxygen content endorse oxidation reaction and result in lessCO
CO emission from preheated biodiesels are lower than neat biodiesel at all loads
Low viscosity of preheated biodiesel increases the atomisation process and lowers the ignition delay andCO emission
Preheating improves spray characteristics and air fuel mixing resulting in low COemission
HC Emission:
HC emissions from biodiesels are lower than Diesel at all loads
Higher Oxygen content in methyl ester promoting combustion and resulting in lesser HCemission
HC emission preheated biodiesels is lower than BD100at allloads
Low viscosity increases atomisation process and lowers ignition delay and HCemission
Increase in combustion characteristics achieved with increase in fuel inlettemperature.
NOx Emission:
NOx emissions from biodiesels are higher than Diesel at allloads
Higher Oxygen content in methyl ester promoting combustion and resulting in higher NOxemission
NOx emission preheated biodiesels is higher thanBD100 at allloads
Increase in combustion gas temperature with increase in fuel inlettemperature.
Smoke Intensity
Exhaust smoke emission from biodiesels are lower than Diesel at allloads
It increases with load for allfuels
Due to lower availability of oxygen for diesel results in high smoke emission
Smoke emission of preheated biodiesels is lesser thanBD100
Viscosity of preheated biodiesel is lesser thanBD100
Combustion is uniform causing lesser smokeemission
Conclusion:
Suitability as a substitute for CI and Emission characteristicsofCashewNutShell OilBiodiesel(BD100andBD100T90)
Reasons for adoption of Cashew Nut Shell Oil – favourable climatic conditions, availability of large uncultivated waste lands,
properties closer to diesel, Non-toxic and free fromsulphur
HC and CO reduce than diesel at all loads by preheating thefuel
samples at three different temperatures
NOx emission are higher thandiesel
Preheating the biodiesel to various temperatures shows continuous increase in NOx emission than Cashew nut bio diesel at allloads
The biodiesel shall be used in unmodified diesel engine. Nomajormodifications are required.
Nitrogen emission:
NOx emissions tested for all fuels NBD100, NBDCeO210,NBDCe$O_2$20,diesel.
NOx emission for NBD100 are 3.3% (at 0.75 bar), 4.1% (at 1.5 bar),4.8%(at 2.25 bar), 5.1%(at 3 bar) and 5.7%(at 3.75bar).
Abundance on oxygen increases the temperature and NOx emissions
NOx emissions from NBD100CeO210, NBD100CeO2are lower than NBD100 (but slightly higher than diesel at allBMEP)
Inclusion of 10 nm and 20 nm particle size of CeO2nano additive, 2.7% and 3.6% lower NOx emissions thanNBD100
CeO_2nano-additive reduce the temperature of soot-oxidation and ensuing lower NOxemission.
NOx emissions at 3.75 bar BMEP 12.8 g/kWh (for NBD100), 12.4 g/kWh (for diesel), 12.1 g/kWh(for NBDCeO210) and 10.5 g/kWh(for NBDCeO220).

II. CONCLUSIONS

Orange Peel oil
Samples exhibit lower HC and CO emissions as compared to theBD100
Corn Oil
COBDE1 and COBDE2 exhibit Lower HC and CO emission
Mustard oil
HC and CO emissions reduced significantly with the addition of DTBP
Neem Bio Diesel with higher alcohol
Smoke opacity decreased for all neem oil biodiesel/alcohol blends.
NOx emission decreased with an increase in alcohol content in the blends
HC emission observed to be lower with two alcohol blends at all loads because of inherent lower energy content
Neem oil biodiesel/alcohol blends ignite earlier than diesel fuel owing to their higher cetane number and result in lower HC emission
Neem BioDiesel withCeO_2
The CO and HC emissions are 4.3% and 4.7% lower for NBD100 than diesel at 3.5 bar BMEP.
CeO_2 nano particle further reduces CO and HC emission 4.2% (for NBDCeO220) and 3.6% (forNBD100)
The degree of NOx emission in NBD100 is 5.6% higher at 3.5 bar BMEP. When compared to NBD100, tail pipe NOx emission
was found to be 2.7% and 3.6% lower when fueled with NBDCeO210 and NBD$CeO_2$20.
When compared to Diesel, tailpipe smoke emission was found to be 1.7% lower when fueled withNBD100.
CeO_2nanoparticle further reduces the smoke emission by 1.6% and 1.8% respectively for NBD$CeO_2$10 and NBD$CeO_2$20 when
compared to NBD100 owing to its improved catalytic activity
Neem Bio Diesel with CNT
The NBD emits 4.8% higher Nox emission compared to diesel at peak load condition
Mahua Oil
CeO_2 reduce Emissions significantly
Biodiesel with 200 ppm of CeO_2 achieved Significant reductions in all the emissions
Cashew Nut Shell Oil
Preheating with increasing temperatures continuously reduces HC and COemission
Nox emission are higher than diesel
Preheating shows continues increase in Nox emission at all loads

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