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Experimental Determination of Performance Characteristics for Cotton-seed oil Biodiesel with Cerium Oxide Nanoparticles

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Abstract

The development in the area of alternative fuels is very fast as the resources of fossil fuels are on the verge of getting finished day by day and along with that there is also a need to reduce the emissions. In recent research, biodiesel has been developed as an effective alternative for existing fuels for CI engines. Biodiesels have shown reduction in emissions except NOx. With the development of nanotechnology, nano-fuels have developed and tested widely along with fuels. Nano-fuels have shown improvement in combustion, emission and performance characteristics of CI engines. The current research is focusing on the effect of cotton seed oil biodiesel with cerium oxide nanoparticles used along with diesel in various concentrations of B6 up to B36 and 35ppm of nano-particles in each of them. The experiment will be carried out on a single cylinder variable compression ratio diesel engine for compression ratios of 16 and 18 and the results will be validated by SEM and TEM diagrams of cerium oxide nanoparticles as well as by Artificial Neural Network method. It is expected that the blended fuel will show better performance than neat diesel. Also it's expected to have less HC, CO and NOx emissions as compared with neat diesel.

Keywords:*biodiesel, transesterification, nanoparticle, cotton seed oil, cerium oxide, performance, emission.*

1. Introduction

A great demand for petroleum products is a prime concern nowadays because of increasing number of vehicles all over the world. So, the depletion of fossil fuel resources is having major effect in all sectors. To meet such ever increasing demands, one of the key areas of research is being conducted in alternative fuel sector to provide a suitable fuel substitute in internal combustion engines. In recent research, biodiesel has been proved to be a good option as an alternative fuel.

In general, biodiesel refers to any fuel alternative obtained from renewable biological resource. Biodiesel are fuels called as fatty acid methyl esters (FAME) which can be produced from a great variety of feedstocks such as vegetable oils, animal fats as well as waste oils.

Another area of research which is increasing further the effectiveness of alternative fuels is the application of nano-sized additives in liquid fuel. Addition of such nano-particles has been proved to be effective as they reduce emissions from engine, shorten ignition delay and yield better combustion of fuel.

Amit et al. [1] have studied the performance of CI engine by addition of iron oxide and cobalt oxide nanoparticles in Jatropha biodiesel. It was observed that nano particles blended fuel showed better thermal properties which resulted in increased brake thermal efficiency, improved brake specific fuel combustion, and reduced exhaust gas temperature relative to neat diesel. The brake thermal efficiency was increased by 0.5%, whereas the BSFC was increased from 0.27kg/kW-hr to 0.28kg/kW-hr as in case of neat diesel.

V. Arul Selvan et al. [2] Investigated the effect of addition of cerium oxide nanoparticles in neat diesel and diesel-biodiesel-ethanol blends. Cerium oxide acts as an oxygen donating catalyst as well as it absorbs oxygen for reduction of NOx. Hence, it is useful in improving combustion of fuel and reducing emissions from engine. The specific fuel consumption was observed to be 0.358kg/kW-hr with cerium oxide nanoparticles, while it was 0.393 kg/kW-hr for neat diesel.

M.M.Rashed et al. [3] studied engine performance and its emission with jatropha, palm and moringa oil biodiesels. 20% of each biodiesel was tested in the diesel engine, and all fuel samples were found to reduced brake power, increase brake specific fuel combustion than diesel; while all blends reduced hydrocarbon and CO emissions as compared to diesel. The CO and HC emissions were reduced by 22.9-32.6% and 11.84-30.26% respectively. Nitric Oxides (NOx) emission was found to increase with the use of blends.

V. Sajith etal. [4] investigated the influence of addition on cerium oxide with biodiesel with different dosing levels on physiochemical properties and biodiesel performance. With inclusion of nanoparticles, flash point and viscosity of biodiesel was increased, whereas HC and NOx emissions were found to be reduced appreciably. Maximum of 1.5% increases in brake thermal efficiency was observed for nanoparticle concentration of 80ppm. A reduction of HC emissions up to 25% to 40% was obtained by adding nanoparticles ranging from 40 to 80ppm.

SupriyaChavan et al. [5] explored the emission of different pollutants with various blends of diesel-jatropha biodiesel fuel mixtures in a variable compression ratio engine. The blends were JB00, JB10, JB20, JB30 and JB100. The compression ratios used during testing were 14,15,16,17 and 18. It was observed that HC and CO emissions were reduced by increasing load and CR, whereas NOx emissions were observed to be increasing with load and CR. Out of this experiment, JB30 and 18 were proved to be the most optimum biodiesel blend and compression ratio respectively. For JB30, CO and HC emissions were reduced by 50% and 43% respectively whereas NOx was increased by 20% for the same.

SupriyaChavan et al. [6] synthesized biodiesel from pongamia oil by using catalyst made out of waste crab shells and used them in engine with diesel in blends such as KB10, KB20, KB30 and KB100. The biodiesel (B00) had calorific value 35.86 MJ/kg. It was concluded that as the blend content increases, HC and Co emissions were decreasing, while NOx emissions were increasing. Out of all blends, KB20 was found to be the one giving least emissions among all. In case of NOx emissions, for neat diesel, it was 1ppm at no load with CR 14 and 223ppm at 12 kg with CR 18. But, the NOx emission, in case of KB20%, was 3ppm at no load at CR14 and 157ppm at 12kg load with CR 18.

K.Vijayaraj et al. [7] compared the performances of cotton seed and mango seed oil biodiesel with diesel. They found that the viscosity of both biodiesels was higher while calorific values slightly lower than that of diesel. They also concluded that both biodiesels can be used in existing diesel without any further modification.

Ajin C. Sajeevan etal. [8] experimentally studied the effects of cerium oxide nanoparticle fuel additives on biodiesel. They also performed stability analysis for nanoparticles and found that the zeta potential, which is a measure of stability of nano-fluids, is the maximum for 35ppm concentration. Due to its phenomenal oxygen buffering capacity, cerium oxide has exceptional catalytic activity at nano-scale and thus reduces NOx and HC emissions by 30% and 45% respectively. It also resulted in improvement in diesel efficiency by 5%. It was also observed that the reduction in emissions is proportional to the concentration level of nanoparticles in diesel and the most optimum dosing level was observed to be 35ppm.

VivekKhond et al. [9] Found that without hampering the engine performance, the best method to reduce particulate matter and NOx emissions is the inclusion of nanoparticles in it. They also discussed the effects of different nanoparticles with different biodiesels on performance as well as emission characteristics. The highest improvement in efficiency was by 16% with 10ppm nanoparticle inclusion.

They also put forth some problems related with nano-fuel additives such as its cost, its traces found in exhaust, its influence on atomization, chances of agglomeration in base fluid in long run.

Narendranathan S.K. et al. [10] concluded that the addition of biodiesel with diesel enhances the engine performance and lessens most of the emissions. It is because of improved cetane number and higher oxygen content of biodiesel. As there is a decrease in brake power and heating value for biodiesel, further work is required to be done.

Kevin Kunnassery et al. [11] studied the effect of nanoparticles additives with diesel fuel on emission characteristics of engine. It was found that with 30ppm of nanoparticles inclusion, mechanical efficiency was improved by 30% as compared with neat diesel, whereas specific fuel consumption was reduced by 0.5kg/kW-hr.

V.Nadana Kumar etal [12] investigated the effect of Aluminum oxide nanoparticles on performance, emission and combustion characteristics of a CI engine. The waste cooling oil biodiesel was used for blending with neat diesel. The best results were obtained with 75 ppm of Al_2O_3 in case of brake thermal efficiency. Also, as the nanoparticle concentration is increased, the NOx emissions are found to be increasing, whereas with CO emissions are going on reducing with the same.

Prabaharan et al. [13] Studied different properties of cerium oxide nanoparticles by various methods such as X-ray diffraction, FT-IR spectrum, SEM and TEM diagrams etc. FTIR analysis confirmed the cubic nature of particles whereas SEM analysis found that the particles are in spherical shape.

2. Material and Methodology

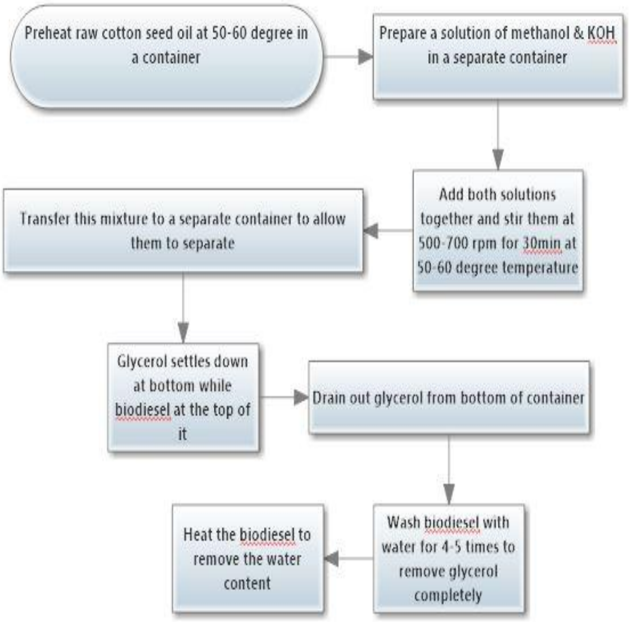

Fig.1: Flowchart of preparation of cottonseed oil biodiesel.

Table 1: Properties of Cotton seed methyl ester

Sr.No.	Property	Value
1	Specific Gravity	0.91
2	Kinematic Viscosity at 40^0C	5.8 mm^2/s
3	Cetane number	52
4	Gross calorific value	40610 kJ/kg
5	Flash Point	162^0C

Table 2: Properties of Cerium Oxide nanoparticles

Sr.No.	Property	Value
1	Purity	99.90%
2	Average Particle Size	20-30 nm
3	Specific Surface Area (SSA)	40-45 m^2/g
4	True Density	6.5 g/cm^3
5	Bulk Density	1.3 g/cm^3
6	Color	Light Yellow
7	Morphology	Spherical

The test will be carried out with different concentrations of cotton seed oil biodiesel and diesel with cerium oxide nanoparticles in a fixed quantity. The blends will be B6, B12, B18, B24, B30 and B36 with CeO_2 quantity of 30 ppm in each case. Here, B6 means 6% of cotton seed biodiesel while 94% neat diesel.

The nanoparticles concentration is set to be at 35ppm based on the optimum values given by previous research. At 35 ppm, as per the research available, the zeta potential of nanoparticles is observed to be the maximum; hence the mixture is more stable.

Nanoparticles will be mixed with biodiesel with the help of ultrasonication process so as to ensure proper dispersion of nanoparticles within the fuel. The performance of neat diesel and that of blends mixed with nanoparticles will be compared. The testing will be done for two different compression ratios of 16 and 18.

3. Experimental Setup

The setup consists of a single cylinder diesel engine that has a facility of changing load with the help of rope brake dynamometer. The engine is facility of changing the compression ratio as per requirement.

The block diagram for the proposed experimental setup is as shown below:

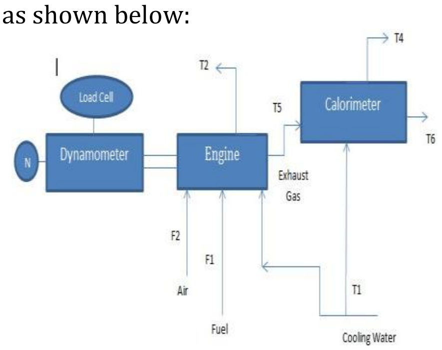

Fig. 2: Block diagram of experimental setup

Where,

T1: Inlet Temperature of cooling jacket water (^0C)
F1: Flow rate of fuel
T2: Outlet Temperature of cooling jacket water (^0C)
F2: Flow rate of air
T3: Inlet Temperature of calorimeter water (^0C)
F3: Flow rate of engine cooling water
T4: Outlet Temperature of calorimeter water (^0C)
F4: Flow rate of calorimeter cooling water
T5: Temperature of exhaust gases before entering the calorimeter (^0C)
T6: Temperature of exhaust gases after passing through the calorimeter (^0C)
N: Engine speed reading by Tachometer (rpm)

Table 3: Specifications of engine

Make	Field Marshal
Type	4 stroke C.I. engine
Displacement	1432 cc
kW rating	5.9 kW
Cylinder	1
Speed	800 rpm
Dynamometer	Rope brake type
Drum Diameter	0.36 m
Maximum Load	36 kg

3.1Components of test setup:

Dynamometer

It is a device that is used to measure force, torque or power. It can also be used in determining torque or power required to drive a machine.

Orifice meter

It is a device that measures the flow rate by restricting the flow. Flow rate can be volumetric or mass flow rate.

Digital Tachometer

It is used for measuring engine speed. It can measure rotational or linear speed using laser or surface contact.

Exhaust Gas Analyzer

It is device used for measuring the emissions such as CO, CO_2, HC, and O2from the engine exhaust. It gives accurate readings.

Calorimeter

It is a device which is used for the process of measuring heat evolved during reactions or physical changes. It can also be used to determine heat capacity.

4. Test Matrix

The engine testing is to be done to determine performance and emission characteristics of diesel blended with biodiesel and cerium oxide nanoparticles. The test matrix is as shown below:

Table 4: Test Matrix for engine testing

Sr. No.	Blend	Compression Ratio	Nanoparticle concentration	Load (kg)
1	B6	16 & 18	35 ppm	5
				10
				15
				20
2	B12	16 & 18	35 ppm	5
				10
				15
				20
3	B18	16 & 18	35 ppm	5
				10
				15
				20
4	B24	16 & 18	35 ppm	5
				10
				15
				20
5	B30	16 & 18	35 ppm	5
				10
				15
				20
6	B36	16 & 18	35 ppm	5
				10
				15
				20

Along with these readings, the data from exhaust gas analyzer will also be recorded for HC, CO and NOx emissions.

5. Validation of Results

The results obtained in this testing will be validated by following method(s):

i. Validation with the help of the experimental data from reference papers

ii. With the help of SEM and TEM diagrams of CeO_2 nanoparticles

iii. By Artificial Neural Network (ANN) method

The results will be plotted separately for both compression ratios with load plotted along X-axis and Emission (ppm) along Y-axis.

6. Conclusions

After conducting the experiment with different blends of diesel-biodiesel with cerium oxide nanoparticles, following results are expected-

i. Reduction in CO, HC and NOx emissions.

ii. Improvement in brake thermal efficiency of engine

iii. Better performance with increasing percentage of biodiesel in the blends.

iv. Improved mixture properties with addition of cerium oxide nanoparticles.

References

[1] Amit, Sudhir Kumar,(2015), Impact on the performance of direct compression ignition engine by adding nano-particle in biodiesel, *Journal of Material Science and Mechanical Engineering*,Volume-2, Number-7, pp.7-9.

[2] V. Arul Selvan, R.B.Anand and M. Udaykumar(2009), Effects of cerium oxide nanoparticle addition in diesel and diesel-biodiesel-ethanol blends on the performance and emission characteristics of a CI engine, *ARPN Journal of Engineering and Applied Science,* Vol-4, No.7.

[3] M.M. Rashed, M.A.Kalam et.al. (2016), Performance and emission characteristics of a diesel engine fueled with palm, jatropha and moringa oil mrthyl ester, *Elsevier Journal/Industrial Crops and Products 79(2016) 70-76.*

[4]V. Sajith, C.B.Sobhan and G.P.Peterson (2010), Experimental Invistigations on the effects of cerium oxide nanoparticle fuel additives on Biodiesel, *Advances in Mechanical Engineering,* Volume-2010, article-581407.

[5]Supriya B. Chavan et al.(2015), Study of Biodiesel blends on emission and performance characterization of a variable compression ratio engine, *American Chemical Society Publications- Energy and Fuels,29, pp.-4393-4398*.

[6]Supriya B. Chavan et al. (2015), Application of an ecofriendly heterogeneous catalyst (CaO) for synthesis of biodiesel and its characterization on VCR engine, *Internatinal Review of Mechanical Engineering, Vol.-9, No.-3*.

[7]K.Vijayaraj and A.P.Sathiyagnanam (2014), Comparative study on properties of methyl ester of cotton seed oil and methyl ester of mango seed oil with biodiesel, *Global Journal of Researches in Engineering: Automotive Engineering, Vol-14 and Issue-2.*

[8]Ajin C. Sanjeevan and V. Sajith (2013), Diesel engine emission reduction using catalytic nanoparticles: An Experimental Investigation, *Journal of Engineering, Vol-2013, Article-589382*.

[9]VivekKhond& V.M. Kriplani(2016), Effect of nanofluid additives on performance and emissions of emulsified diesel and biodiesel fueled stationary CI engine: A comparative review, *Elsevier-Renewable and Sustainable energy reviews 59(2016) 1338-1348*.

[10]Narendranathan S.K. & K. Sudhagar (2014), Study on Performance and emission characteristic of CI engine using biodiesel*, Journal of Advanced Material Research, Vols-984-985, pp: 885-892*.

[11] Kevin Kunnassery, Sameer Jackeray and SuprabhatMohod (2015), Analysis on Emission characterstic from a CI engine using nanoparticles as a fuel additive, *International Journal of Latest Trends in Engineering and Technology, Vol.-6, Issue-2*.

[12]V.Nadana Kumar, N.M.Venkatesh and N.Alagumurthi (2016), Influence of Aluminum Oxide nanoparticles blended with waste cooking oil in the performance, emission and combustion characteristics on a DI diesel engine, *Journal of Advanced Engineering Research, Vol.-3, Issue-1, pp.-66-71*.

[13]Prabaharan et al. (2016), Structural, optical, morphological and dielectric properties of cerium oxide nanoparticles*, Journal of Material Research 2016; 19(2):478-482*.