Evaluation of Blended Biodiesels with Nanomaterial Additives: A Review

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Abstract

This report is a comprehensive review on performance, emission and combustion characteristics of a diesel engine fueled with diesel, biodiesel and its blends with the nano-metal additives such as Aluminum oxide, copper oxide, zinc oxide, ferrous oxide and cerium oxide. Many researches were done on various biodiesels and additives used for blending of biodiesels and still going on. The main aim of these researches is to reducing the cost of fuel, more efficient fuel, increase the life span of engine and to reduce the emissions coming out from engines or due to the usage of the fossil fuels. This study mainly focuses on biodiesel with nano metal oxide additives to improve the performance characteristics and combustion characteristics of the engine and to reduce the fuel consumption, cost of the fuel and reducing emissions evolving from the engines in the form of exhaust gases.

Keywords: nano-metal additives, blending, biodiesels, performance.

Introduction

German scientist named Rudolf diesel is the inventor of Diesel engine. His engine was designed for use of coal dust, peanut oil and other vegetable-based oils as a fuel, but later after conducting various experiments diesel is being used as fuel for compression ignition (CI) engines. Diesel can be extracted from crude petroleum oil by fractional distillation process at about 270°C After extraction of diesel from crude oil, the diesel will be refined for removing the impurities present in it. The refined diesel can be used in various purposes like for transportation sector, agricultural sector, construction sector and for power sector etc. As the population all around the world is increasing rapidly day by day, fuel consumption is also increasing which leads to depletion in fossil fuel resources, increase in the cost of the fuel and increase in greenhouse gases like Hydrocarbons, carbon monoxide, carbon dioxide, oxides of the nitrogen and the particulate matter. The increase in amount of greenhouse gases causes global warming which includes rise in temperature, improper and irregular rain fall, melts the glaciers hence rise in sea-level etc. In the process to overcome or reducing these problems the development for alternative fuels has been promoted. Many researches were done on these alternative fuels and still going on. The various from which the biodiesel could be extracted is shown in table 1.

Table 1: Different sources of extracting biodiesel [1]

Primary biodiesel	Natural bio-fuel	Fire wood, animal waste, land fill gas, crop residues etc.
Secondary biodiesel	1st generation bio-fuel	Sugarcane, wheat, corn, potato, peanut oil, soybean oil, rapeseed oil, mustard oil, palm oil, sunflower oil etc.
Secondary biodiesel	2nd generation bio-fuel	Non-edible vegetable oil (mahua, jatropha, karanja, cotton seed, annona squamosa seed etc.), grass, waste recycled oil, animal fats (beef tallow, yellow grease, pork, fish oil etc.).
Secondary biodiesel	3rd generation bio-fuel	Microbes, micro algae etc.

G. Bhaskar et al. [2] were conducted experiments on Manganese doped Zinc oxide nano catalyst as a heterogeneous catalyst for producing biodiesel with less activation energy. They investigated the crystalline nature of manganese doped zinc oxide Nano

catalyst by X-Ray diffraction (XRD), morphology of catalyst using SEM analysis, raw mahua oil was analyzed by using FT-IR analysis and observed the effects of the oil to the methanol ratio, and manganese doped zinc oxide Nano catalyst concentration, reaction time and temperature, reusability of manganese doped zinc oxide Nano catalyst on yield of biodiesel. They concluded the manganese doped zinc oxide nanoparticles which are calcined at 600°c represented the maximum catalytic activity and both the mahua oil and manganese doped zinc oxide nano catalyst are suitable for the production of biodiesel in a large scale. The various nano metal oxides and their properties are listed in table 2.

Table 2: Properties of Nano metal oxide particles

Property	Al_2O_3	CuO	ZnO	Fe_2O_3	CeO_2
Purity %	99.9	99.9	99.9	99.5	99.9
Particle size nm	30-50	30-50	30-50	30-50	20-30
Bulk Density g/cm^3	1.5	0.79	0.28-0.48	-	1.3
True Density g/cm^3	3.97	6.4	6	5.24	6.5
Morphology	Spherical	Spherical	Nearly spherical	Spherical	Spherical
Atomic Weight g/mol	101.96	79.54	81.38	159.69	172.1148
Colour	White	Black	Milky white	Reddish brown	Light yellow

C.Syed Aalam et al. [3] were conducted various experiments on four stroke single cylinder common rail direct injection (CRDI) diesel engine with B20 blend of mahua biodiesel by adding two variants of aluminum-oxide nanoparticles as additive. They used ultrasonicate and homogenizer with cetyl the trimethyl ammonium bromide as cationic surfactant for blending of the biodiesel and aluminum oxide nanoparticles. Substantial enhancement in the brake thermal efficiency and a slight reduction in pollutants like CO, HC, and smoke were observed from their experiments and the operation of common rail direct injection diesel engine was normal and smooth by using mahua oil biodiesel blend of B20 when it is added with different proportions of aluminum nanoparticles as an additive to the biodiesel.

S. Debbarma et al. [4] were experimented on a single cylinder diesel engine with palm oil biodiesel and iron nanoparticles of 50ppm and 75ppm as an additive for performance and emission characteristics. By their experiments they concluded that advanced heat release, shorter ignition delay, increase in BTE by 3% and BSFC by 3.3%, slight reduction in CO and NO_x emissions in comparison to diesel, and increase in density, calorific value and viscosity of fuel blend with increase in concentration of iron nanoparticles.

A.Syed et al. [5] were conducted various experiments on a single cylinder four stroke direct injection diesel engine having a rated power 3.5kW at a rated speed of 1500rpm with four different injection operation pressures of 200, 225, 250, and 275 bar which is compared using the operation of diesel at 200 bar pressure as the baseline. The engine is operated on dual fuel mode with hydrogen and mahua oil methyl ester. Observations of these experiments are minimum brake specific fuel consumption, maximum brake thermal efficiency, and less CO, HC and smoke emissions with increase in NO_x concentration were obtained at injection operation pressure of 250 bar for dual fuel mode of B20 hydrogen. Decrease in BTE, increase in CO, HC and smoke emissions were observe with increase in injection operation pressure to 275 bar. They concluded the injection operation pressure of 250bar for B20 hydrogen dual fuel mode is optimum.

Swarup kumar nayak et al. [6] investigated on production of biodiesel using neat mahua oil through base catalysed transesterification process and blending of biodiesel with dimethyl carbonate additive in different proportions to generate different test fuels for applying on water cooled single cylinder diesel engine. The results obtained with their experiments are increase in additives in mahua oil leads to increase in brake thermal efficiency, decrease in brake specific fuel consumption due

to better combustion, decrease in exhaust gas temperature, less CO, NO_x, smoke and HC emissions when compared to mineral diesel.

Devarajan et al. [7] conducted experiments on twin cylinder four stroke direct injection diesel engine of 21kW with mahua biodiesel by adding ferrofluid nanoparticles of 14nm and compared with conventional diesel fuel. They found that the emissions of CO, HC, and smoke are less, and less in-cylinder pressure in biodiesel blend with ferrofluid than biodiesel and conventional diesel when compared with each other. Kinematic viscosity of biodiesel without ferrofluid is high so it created more ignition lag and higher Heat release rate. The brake thermal efficiency of biodiesel with ferrofluid at full load is higher than normal biodiesel of same blend and adding of nano ferrofluid improved the properties of the fuel.

F.Sundus et al. [8] have analysed the different tribology aspects like properties of biodiesel, metal contamination, storage time, temperature, and moisture absorption. They discussed the various factors affecting the usage and stability of the biodiesel and the refining techniques for improving stability of biodiesel and the possible remedies for improving biodiesel's stability were summarized.

M.Vijay kumar et al. [9] has explained about the effects of additives on combustion, performance and emissions for biodiesel. Their review concludes that the additives plays an important role in increasing the engine's performance, combustion and emission characteristics, and using additives on second generation biodiesel are better than petro-diesel and biodiesel.

Chiranjeeva rao seela et al. [10] has conducted various experiments with zinc oxide nanoparticles on diesel and mahua biodiesel fuel on a single cylinder diesel engine for performance characteristics. They have implemented Generalized regression neural network (GRNN) on the engine for performance characteristics at different operating conditions. They concluded that with B20 biodiesel and zinc oxide nano metal additives Brake thermal efficiency is increased by 2-3% and NO_x emissions are also less when added with 50ppm and 100ppm of zinc oxide nanoparticles, GRNN predictions and experimental values are very close and this can be used for predicting unknown findings of experiments and it requires less labor, cost and time.

Hariram venkatesan et al. [11] gave a brief review on fuel's physical and chemical properties, performance and emission characteristics of the engine when using the nano metallic additives with diesel and biodiesel. They compared the properties of fuel i.e. flash point, fire point, kinematic viscosity, density, calorific value and cetane number of various blends and composition of additives of diesel and biodiesel. They also compared the performance characteristics (BTE and BSFC) and emission characteristics of unburnt hydro carbons, carbon monoxide and oxides of nitrogen of different fuel blends with different metal additives of various compositions at different testing conditions and concluded that nano metal additives is having a prominent role for improving the properties of fuel and its performance and emission characteristics. Aluminum oxide, aluminum, carbon nano tube and cerium oxide gave good results when compared with zinc oxide and the addition of zinc oxide nanoparticles should be more than other nanoparticles to obtain equivalent results. Based on the fuel and fuel blend used, the number of additives must be optimum for obtaining better results.

Sanghoon lee et al. [12] were conducted various experiments with different blends of Karanja biodiesel (KB40, KB60 & KB100) on spray characteristics for injection pressures of 50MPa, 100MPa and 150MPa and performance and emission characteristics were analyzed at various operating conditions of the engine. To investigate the effects of Karanja biodiesel blending ratio on injection rate, spray evolution and spray behavior they did spray investigation. They observed that the maximum injection rate and transient motion of needle were influenced by fuel properties such as density and viscosity, the biodiesel's higher viscosity slows down the needle's movement at FIP (fuel injection pressure) of 50MPa but with increase in FIP the fuel flow rate is increased and higher density of biodiesel blends increased the maximum rate of fuel. When biodiesel blends compared with diesel the maximum torque, brake thermal efficiency and exhaust gas temperature were less and brake specific fuel consumption

is high. Smoke is less with KB40 biodiesel blend but particulates below 50nm were more because of its lower volatility and higher viscosity. Combustion duration is longer with KB40 blend at a speed of 2500 rpm than baseline diesel.

K. Krishna et al. [15] were investigated on single cylinder four stroke water cooled DI diesel engine and at a constant speed of 1500rpm with palmstearin methyl ester as fuel of B100 blend and aluminum oxide nano particles as additives to study the effects of the metal additive in biodiesel. Their results shows due to the high oxygen in aluminum oxide nano particles for blends of 150ppm and 200ppm BTE is reduced and for pure biodiesel and 50ppm blend have better BTE and it is relatively same for diesel and biodiesel with 50ppm aluminum oxide nano particles, slight increment in BSFC with biodiesel and its blends respectively, slight decrement in CO_2 and NO_x emissions in biodiesel blends, increment in NO_x emissions for pure biodiesel because of its reactive nature at high temperature, unburnt hydrocarbons were relatively same for all blends, less CO emissions for biodiesel blends with additives because of the oxygen molecules present in the additives and they converted the carbon monoxide to carbon dioxide.

Sivakumar Muthusamy et al. [16] were conducted various experiments on single cylinder DI diesel engine for combustion, performance and emission characteristics with pongamia methyl ester blended with aluminum oxide nano particles at different engine operating conditions and constant speed. The results of their experiments indicate that the BTE has a slight increment and BSFC has decrement with additives. Emissions such as CO, HC and smoke were decreased when compared with Mineral diesel and NO_x emissions were increased. Rate of heat release and gas pressure in cylinder increased with increasing fraction of nano particles of aluminum oxide due to the increase in surface area of nano particles to their volume ratio.

Chandravati et al. [19] were evaluated the thermo analytical characteristics of the biodiesels which are produced from Flaxseed and Mustard oil, and Karanja and Mahua oil methyl esters. They have employed transesterification for mustard oil and flax seed oil, and due to high free fatty acid content in non-edible oil they employed two stage transesterification process for production of biodiesel. These resulted in more oxidative stability of non-edible esters than edible esters due to the more saturated components in non-edible esters and this led to cold flow property of fuel and the methyl ester's viscosity is less than viscosity of oils of raw vegetables.

Senthil Ramalingam et al. [20] reviewed about the effects of antioxidant additives and operating parameters with bio diesels and with the study they concluded loss of brake thermal efficiency with biodiesels because of their high viscosity which led to the poor atomization, increase in brake specific fuel consumption, and reduction in unburnt hydrocarbons, oxides of carbon and smoke emissions because of the high oxygen content present in biodiesel, increase in NOx emissions and the antioxidants are having a prominent role in different parameters when added with biodiesel.

Shikha Gangil et al. [21] were prepared the biodiesel with three step method which consists Saponification, acidification and esterification with colloidal silicate (Ludox) and fumed silica for purifying the biodiesel. The used absorbents were re-used as adsorbents to remove the glycerin from the biodiesel and to evaluate effectiveness of purity of biodiesel. They observed the higher yield when ludox was used at 100^0c with an acid catalyst H_3PO_4 and base catalyst NaOH. It enhances the glycerol movement in liquid stage and the adsorption affinity and capability of adsorption of silica were minimized.

M. Senthil Kumar et al. [23] conducted various experiments to study the influence of various high octane-fuels like eucalyptus oil, methanol and ethanol on combustion behavior of a single cylinder diesel engine with mahua-oil based dual fuel. The energy released by eucalyptus oil is more than methanol and ethanol, Methanol showed more reduction in the cycle temperature because of its higher latent heat of the vaporization, ignition delay is higher after 40% load, increase in duration of combustion of fuel, increase in Brake thermal Efficiency, higher smoke and lower NO_x emissions are observed.

K. Prasada Rao et al. [27] investigated on IDI engine with Diesel, Methanol additive and mahua methyl ester blends. The experiments were carried on load and fuel parameters to study BTE, BSFC, Exhaust gas temperature, unburnt hydrocarbons, CO, CO_2, O_2, NO_x, and smoke. Taguchi method and Grey relational analysis were used to reduce cost and time and validation is given by response surface methodology. The conclusions from these experiments are mahua methyl ester will be used as an alternative fuel, using of taguchi method and grey relational analysis helps to reduce the cost and time and identified the parameters influencing the characteristics, reduction in HC and CO emissions, Grey relational analysis is simple and efficient technique, the error of validation results with experimental results is 0.097, it is relatively same for both the procedures.

H. Raheman et al. [31] have conducted various experiments to investigate about fuel properties and performance of a four stroke, single cylinder, and Ricardo E6 engine of compression ratio 18:1 with Madhuca indica biodiesel of different blends (B20, B40, B60 & B80). They found reduction of density when the Mahua oil is converted to Biodiesel, increase in viscosity and decrease in calorific value of biodiesel with increase in concentration, higher flash point than high speed diesel, pour point depends on blending of biodiesel, less ash content, increased BSFC and decreased BTE, less smoke, lower CO emissions and NO_x emissions. They concluded that B20 blend has more similar properties as mineral diesel than other blends and also it is more efficient for performance and emission characteristics.

Conclusion

Following exhaustive conclusions could be drawn from this present study:

1. Manganese doped zinc oxide nanoparticles which are calcined at 600°c represented the maximum catalytic activity and both the mahua oil and manganese doped zinc oxide nano catalyst is suitable for the production of biodiesel in a large scale.
2. Operation of common rail direct injection diesel engine was normal and smooth by using mahua oil biodiesel blend of B20 when it is added with different proportions of aluminum nanoparticles as an additive to the biodiesel.
3. Advanced heat release, shorter ignition delay, increase in BTE by 3% and BSFC by 3.3%, slight reduction in CO and NO_x emissions in comparison to diesel
4. Smoke is less with KB40 biodiesel blend but particulates below 50nm were more because of its lower volatility and higher viscosity
5. Higher yield when Ludox was used at 100^{0}c with an acid catalyst H_3PO_4 and base catalyst NaOH.

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