



Sustainable Fuel Innovation: The Role of Nanoparticles in Advancing Diesel–Biodiesel Mixtures

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Abstract

Because of its closed carbon cycle, biodiesel is an unmatched alternative fuel source that is intended to address the importance of diesel fuel and lower greenhouse gas emissions. Nevertheless, it is not appropriate in cold weather, increases nitrogen oxide emissions, and requires frequent engine part replacement owing to clogging. When metallic, non-metallic, oxygenated, organic, and amalgamation nanoparticles are added to diesel-biodiesel emulsion fuels, the engine's performance, thermophysical characteristics, heat transfer rate, fuel mixture equilibrium, and exhaust emissions are all improved. The goal of the review is to illustrate the latest nanoparticle additions utilized in diesel-biodiesel fuels.

Keywords : Engines , Nanoparticles , Biodiesel , Diesel Engine , Performance Emission testing

Introduction

Research on clean and sustainable energy resources that are realistically feasible, easily available, and universally suited has been strengthened by the rapid increase in the need for energy supplies, the decade-old environmental effect, and fluctuating energy costs [6-7

]. Biodiesel, which is consistently produced from vegetable and non-edible oils, leftover cooking oils, and animal fats like tallow and lard, is one such renewable fuel source. A few disadvantages of using biodiesel fuel in diesel locomotives include high NOX emissions, poor fuel atomization, piston ring sticking, a 10% energy-based fuel budget reduction, slightly higher density, lower cloud and pour points, and issues with cold starting. [2, 6]. By employing a few relatively new techniques, like accumulating fuel additives and hybrid fuel, which improves engine enactment and efficiency and reduces exhaust emissions, these restrictions can be circumvented. The nanoparticles have proven to be a novel and exciting addition. Nano-additives in biodiesel

have the ability to change a number of fuel properties, including density, sulfur content, and volatility [2,7]. The sizes and forms of a few nanoparticles are compared to typical materials in Figure 1.

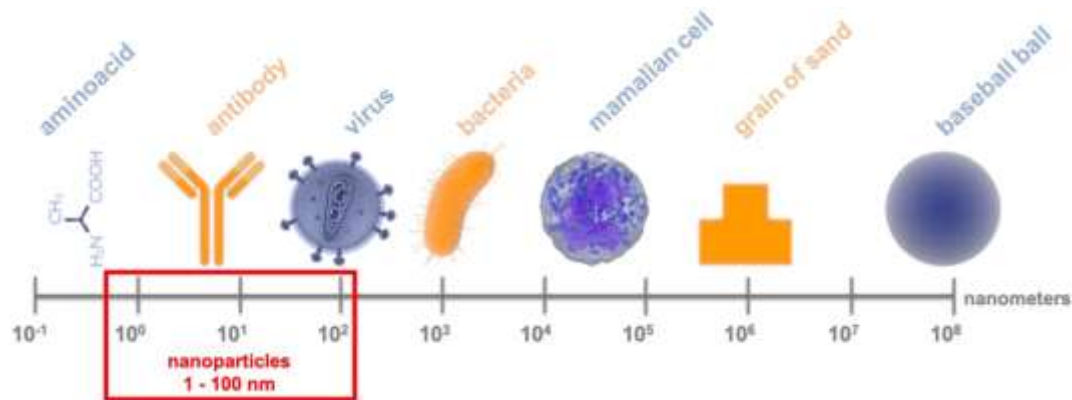


Fig.1 nano material size comparison

The nanoparticles improve ignition physiognomies and function as a secondary energy transporter in liquid fuels. The most popular and effective nanoparticle additions for biodiesel, as well as their implementation and emission characteristics in diesel engines, are covered in the literature. The oxides of carbon nanotubes, graphene, copper, aluminum, and cerium are succinctly described. The potential of nanoparticles utilized in various biodiesel mixes is highlighted in this innovative study, which raises the demand and value of existing biodiesel fuels.

Role and importance of nano materials in blends of Bio diesel Carbon Nanotubes (CNT)

They have a cylinder-shaped nano structure and are allo tropes of carbon. Raising the CNT concentration raises the cetane number, lowers BSFC, and accelerates evaporation due to the catalytic activity of CNT as shown in fig 2. Sadhik et al. claim that the CNT in Jatropha biodiesel raises the BTE by 3%. Additionally, NO_x emissions and ignition delay time are decreased when CNT mixed water-biodiesel emulsion fuel is added [4]. The CNT-Jatropha emulsion fuels are associated with the combined effects of micro-explosion and secondary atomization; the range of harmful pollutants in the output gases was significantly reduced, and ignition rates were improved when compared to the clean JME [5].



Fig 2. An image of Carbon Nano Tube.

The development of micro-explosion in the diesel-metal nano-additive is shown in Figure 3. During the process of formation they found that 90 ppm of MWCNT in jatropha biodiesel B20 increased the engine power by 7.81% and increased the BP related with the neat diesel deprived of any nano-additives.

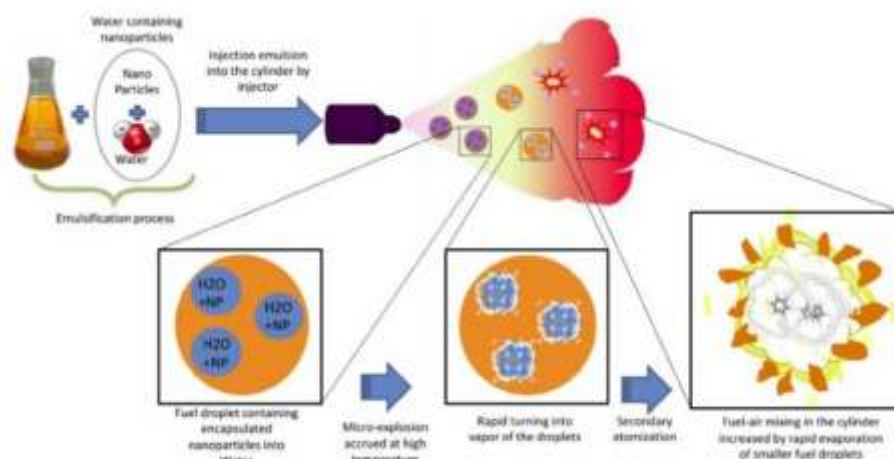


Fig 3. The formation of micro-explosion in the diesel-metal nano-additive.

Copper Oxide (CuO)

A black solid, it is more stable than Cu_2O , which acts as a p-type semiconductor and is thermally stable up to $1,320^\circ\text{C}$. It is insoluble in water but dissolves in acids to form copper salts.

Formation: Can be formed by heating copper in air or through the thermal decomposition of copper(II) salts. The fig 4. Shows the structural formation image of CuO.

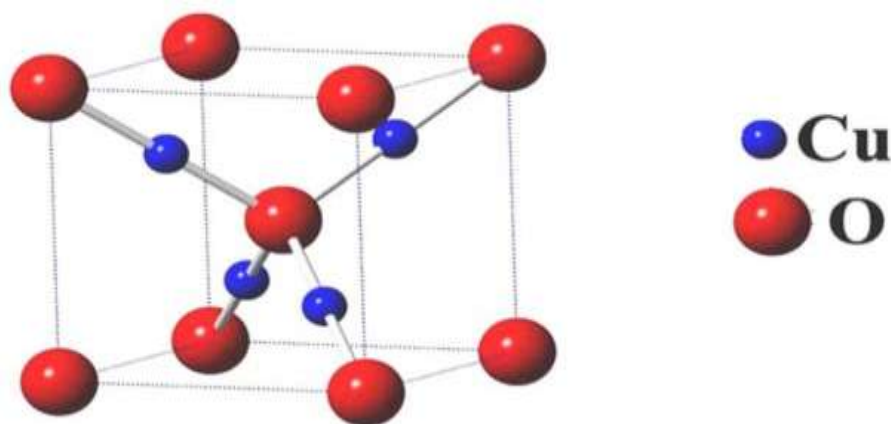


Fig 4. The structural formation image of Copper Oxide (CuO).

CuO functions in biodiesel as an oxygen promoter and catalyst. It reduces NO_x by acting as a transition metal oxide, which helps transfer heat from the engine to the exhaust. The BTE is raised by 7% when *Pongamia pinnata* biodiesel is combined with CuO nanoparticles [8]. CuO can be converted to metallic copper at high temperatures, when in contact with CO or hydrogen. CuO increases the cetane index and flash point temperature of biodiesel while acting as a combustion catalyst for hydrocarbon fuels. CuO lowers the BSFC and CO₂ and NO_x emissions when added to biodiesel. Nevertheless, kinematic viscosity and flash point somewhat increased in comparison to clean biodiesel [9]. Table 1 shows how the dosage level of nanoparticle additions affects the efficiency of CI engines' operation and emission characteristics, according to multiple researchers.

Table 1. Effect of dosing level of nanoparticle additives on performance and emission characteristics of CI engine.

Cerium oxide (CeO₂)

CeO₂ nano particles support the oxidation of hydrocarbons in biodiesel by acting as thermally stable oxidation catalysts. Through a relatively low-energy response, CeO₂ changes from the stoichiometric CeO₂ (+4) valence state to the Ce₂O₃ (+3) state. CeO₂ is converted to cerous oxide (Ce₂O₃) and supplies the oxygen needed for the HC and soot discount. After enhancing the primary ignition cycle, Ce₂O₃ remains dynamic, reoxidizes to CeO₂, and lowers NO_x [2, 3]. According to Sajith et al. [3],

adding CeO₂ to Jatropha biodiesel reduces BSFC because it oxidizes carbon residue from engine resulting in full combustion, smooth operation, and efficiency.

Graphene Oxide (GNPs)

It is displayed as a novel wonder molecule and is a layer of carbon that is one atom thick. The rigidity, two-dimensional structure, and high area-volume ratio of graphene oxide enhance the base fuel's thermal conductivity and thermal transport properties [10].

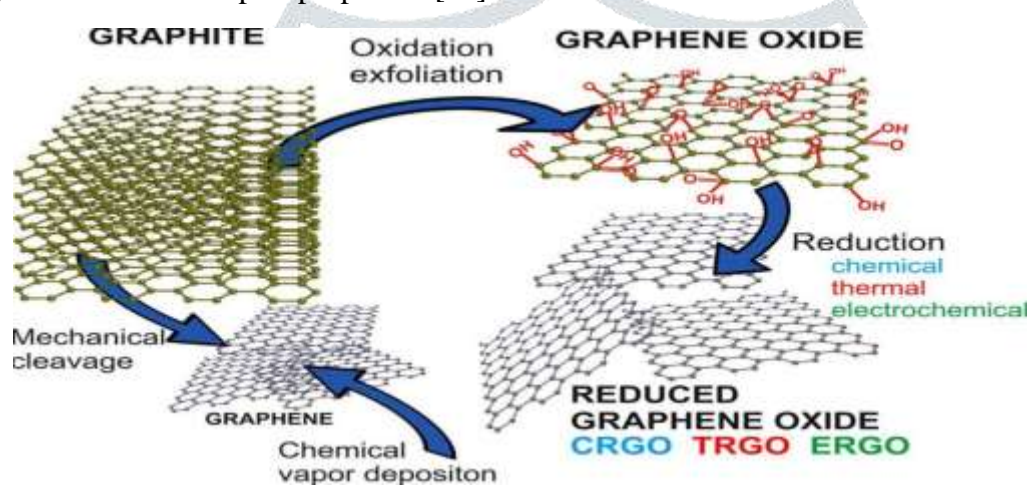


Fig 5. Formation of Graphene Oxide (GNPs)

When GNPs are combined with biodiesel, performance attributes like BTE and BP are enhanced, emissions are decreased, and catalytic activity is improved. The increased dosages of Simarouba biodiesel's GNPs lower smoke emissions [11]. Change in the activity of catalysis. Smoke emissions are decreased by the increased GNP dose levels in Simarouba biodiesel [11]. CO is reduced by 65% when 25–50 mg/L of GNPs are added to a Jatropha biodiesel blend [13]. The GNPs in Ailanthus altissima biodiesel (B10G90) were reported by Hoseini et al. [14]. Lowers CO emissions by 18.55%. The fuel blend DSOME2040 (B20+40 ppm GNPs) showed an overall improvement in the engine factors and a decrease in exhaust emissions when Soudagar et al. [2] examined the impact of GNPs on dairy scum oil methyl ester- diesel fuel mix.

Aluminium Oxide (Al₂O₃)

Al₂O₃ is a metal oxide with a wide range of industrial uses. Al₂O₃ provides a large surface area for interaction and acts as a catalyst during combustion. While the concentration of smoke and NO_x drops, Al₂O₃ raises the total combustion heat. Process of combustion. While the quantity of smoke and NO_x falls, Al₂O₃ raises the total combustion heat. Because biodiesel contains Al₂O₃ nanoparticles, the ignition delay decreases as ultimate pressure and heat discharge rate increase [2]. Seesy and colleagues [12] investigated the impact Al₂O₃ nanoparticles with Jojoba biodiesel (JB20D) result in reduced flashpoint values while increasing viscosity, cylinder pressure, and density values since Al₂O₃ has a high oxygen content. According to Gumus et al. [9], adding 50 ppm of Al₂O₃ to biodiesel causes a slight increase in torque of 1.0% and blood pressure of 3.28%. The entire process of analyzing fuel blends containing aluminum oxide nano-additive in a diesel engine is depicted in Figure 6. Al₂O₃ nanoparticles at high temperatures dissociate into Al₂O and oxygen as shown in Equation (1) and (2):

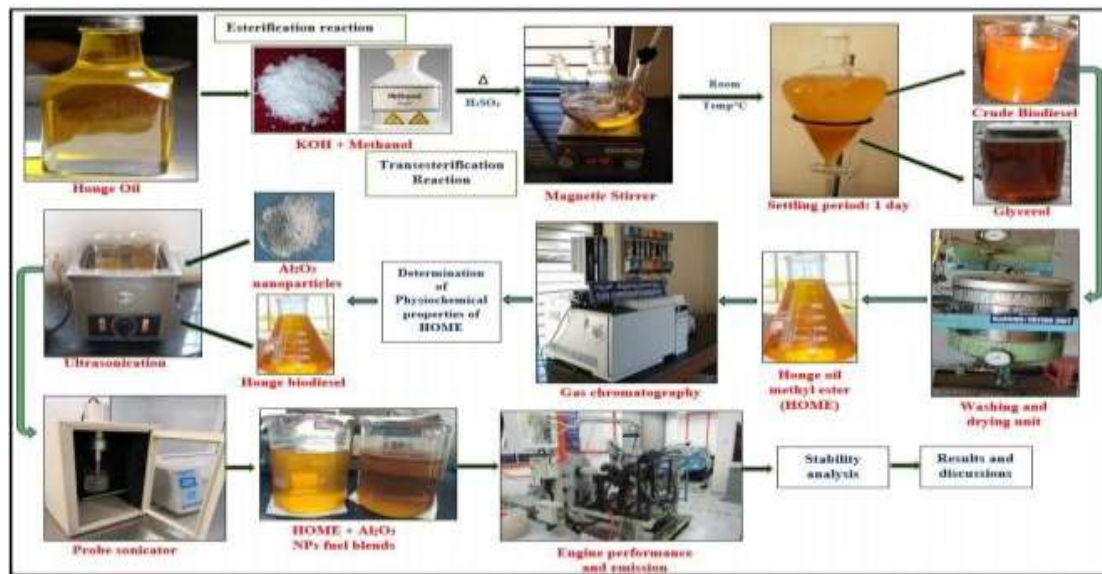
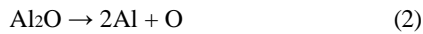
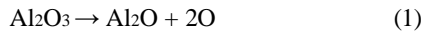


Fig 5. Comprehensive phases convoluted in the study of Aluminium oxide nano- additive fuel blends in diesel engine.

Table 1. Effect of dosing level of nanoparticle additives on performance and emission characteristics of CI engine.

Ref	Base fuel	Nanoparticle additive	Composition (ppm)	NO _x (%)	CO (%)	HC (%)	BSFC (kg/kW-h)	BTE (%)
7	Waste cookingoil (B20)	CeO ₂ -MWCNT	90	18.90 Decr	38.80 Decr	71.40 Decr	0.2501 Decr	-
8	Pongamia pinnata (B20)	CuO	50	2.63 Decr	-	8.33 Incr	0.543 Decr	2.75 Incr
10	Jatropha-n-Butanol (JME40B)	GNP-MWCNT	50	45 Decr	55 Decr	50 Decr	0.2609 Decr	20 Incr
11	Simarouba (SME2040)	GNP	60	12.71 Decr	42.85 Decr	15.38 Decr	-	9.14 Incr
12	Jojoba (JB20D)	Al ₂ O ₃	50	2.63 Decr	-	8.33 Incr	0.543 Decr	2.75 Incr

CONCLUSION AND FUTURE RECOMMENDATION

There are many benefits of adding nanoparticle additions to biodiesel, including improved performance, improved combustion characteristics, and lower emissions. The study's conclusions are as follows:

1. Every oxygenated addition shortened the ignition delay time and raised the cetane number.
2. Engine performance, calorific value, and emissions are all improved by metallic and carbon nanotube nano-additives.
3. As the dosage of nanoparticle addition increases, the BSFC falls because of improved catalytic oxidation and thorough ignition of biodiesel.
4. Research on the long-term stability of nanoparticles in biodiesel is necessary, as otherwise impedes the future commercialization of nanoparticles.
5. Before metallic and carbon-based NPs are fully introduced into the market, their effects on the environment and human health should be taken into account.
6. Since the nanoparticle additives are not economically viable, new techniques should be investigated and used to produce nano-additives in large quantities at a low cost.

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