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Influence of Alumina Nano Additive on Compression Ignition Engine Characteristics Fueled with Mahua Biodiesel

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Abstract

Alternative internal combustion (IC) engine fuels are being tested due to increased energy consumption and pollutants. Biomass waste, algae, and plant seeds produce alternative energies. Petroleum-based IC engines cause many environmental issues. Thus, adopting an alternative fuel to an engine may require design changes to match conventional fuel performance. Mahua biodiesel and diesel blends with Al_2O_3 (Alumina) nano additive were tested in a single-cylinder compression ignition engine. Mahua biodiesel and its diesel blends with Al_2O_3 nano additive were tested in a single-cylinder compression ignition engine. Different fuels tested the engine. Mahua biodiesel blends 10%, 20%, 30%, 40%, and 100% were tested for performance and emissions at varying loads. Compared to other biodiesel blends, 30% Mahua biodiesel + 70% diesel (B30) performed well and had low tailpipe emissions. Nano additive mixed biodiesel was made with 70% diesel, 30% mahua biodiesel, and 10, 40, and 70 ppm nano Al_2O_3. The 70-ppm alumina nano additive mixed biodiesel has improved thermal efficiency and lower emissions because nanoparticles improve fuel atomization. BTE (Brake thermal efficiency) and BSFC (Brake specific fuel consumption) of 70 ppm alumina nano blended biodiesel increased 4% and lowered 10%, respectively, compared to diesel. Mahua biodiesel blended biodiesel reduced HC (Hydrocarbon), CO (Carbon monoxide), and NO_x (Nitrogen oxides) emissions by 49%, 50%, and 16%, respectively. Nano mixed Mahua biodiesel was a better alternative energy for unmodified CI (Compression ignition) engines.

Keywords

Alumina, Nano additive, CI engine, Mahua biodiesel, Pollution management

Introduction

Diesel engines exhibit superior fuel efficiency in comparison to gasoline engines owing to their elevated compression ratios and lower operational speeds, hence mitigating energy losses attributed to friction. Additionally, these engines have a greater torque output, rendering them very suitable for tasks requiring substantial power and endurance [1]. It is imperative to address these deficiencies in IC engine technology in order to enhance their operational efficiency and mitigate their ecological footprint. The advancement of engine design, fuel efficiency, pollution management, and exploration of alternative fuels necessitates ongoing research and development efforts [2]. Fossil fuels possess a limited quantity and are undergoing depletion at a concerning pace. Furthermore, the extraction and utilization of these resources can yield substantial adverse environmental consequences, including but not limited to air and water contamination, habitat degradation, and the release of greenhouse gases that contribute to the phenomenon of climate change [3].

Consequently, there has been a growing inclination towards the use of renewable energy sources, including wind, solar, and hydropower, due to their environmentally friendly nature and long-term viability [4]. On the other hand, it is noteworthy that renewable energy sources, such as solar, wind, and hydropower, provide several notable benefits, which encompass their inexhaustible nature, environmentally friendly characteristics, and frequently superior cost- effectiveness over extended periods of time [5]. Consequently, there is a growing inclination to shift from fossil fuels to renewable energy sources in order to address these constraints. Biofuels refer to a category of fuels that are derived from organic matter, including but not limited to plants and animal waste [6]. Renewable energy sources are classified as such due to their origin from live or recently existing organisms, hence possessing the ability to be refilled over a period of time [7]. Biofuels have the potential to serve as a viable alternative to fossil fuels for several applications, including transportation, residential and commercial heating, and electricity generation. In general, the utilization of biofuels presents a multifaceted matter necessitating meticulous examination of its ecological, financial, and societal ramifications [8].

Ongoing research is being conducted to explore novel and environmentally friendly biofuel alternatives. Simultaneously, politicians are actively engaged in formulating laws and regulations that aim to encourage the adoption of biofuels while mitigating their adverse effects [9]. In general, biofuels present a viable and enduring substitute for fossil fuels, exhibiting the capacity to address climate change, enhance energy stability, and foster economic progress [10]. Nano additives refer to a category of materials specifically engineered to augment the characteristics of a given substance through the addition of minute quantities. Nano additions have been found to enhance the performance of biodiesel and mitigate emissions [11]. Furthermore, the utilization of nano additives has the potential to enhance the storage and handling characteristics of biodiesel. This includes the reduction of viscosity and the prevention of sediment formation [12]. In general, the incorporation of nano additives in biodiesel exhibits promising prospects for enhancing its efficacy and mitigating its ecological repercussions, hence facilitating the broader acceptance and utilization of biodiesel as a sustainable energy alternative [13]. Nevertheless, additional investigation is imperative in order to comprehensively comprehend the impacts of nano additives on biodiesel and to guarantee their safety in relation to engine performance and environmental concerns [14]. Mahua biodiesel that was coupled with nano additive because of a modest decrease in harmful emissions (CO, HC, NO_x, and smoke) [15]. The present study evaluated the experimental inquiry conducted on a CI engine, which was fueled with Mahua biodiesel and various diesel mixes containing alumina nano additive. The engine underwent analysis using several test fuels. The performance and emission characteristics of Mahua biodiesel blends, consisting of 10%, 20%, 30%, 40%, and 100% concentrations, were evaluated under various load circumstances. The experimental results indicate that the fuel blend consisting of 30% Mahua biodiesel and 70% diesel (Referred to as B30) exhibited satisfactory performance and tailpipe emissions when compared to other mixes of biodiesel [16-19]. The production of nano blended biodiesel involved a composition consisting of 70% diesel, 30%Mahua biodiesel, and varying concentrations of nano Al_2O_3 at 10, 40, and 70 ppm.

Experimentation

Biodiesel production

The transesterification process involves the conversion of Mahua seed oil into biodiesel through a chemical reaction with methanol and a catalyst. As a consequence, the synthesis of Mahua methyl ester occurs, afterwards serving as a precursor for the production of biodiesel. The experimental procedure entails the combination of a volume of one liter of unprocessed mahua seed oil, a volume of 250 ml of methanol, and a mass of 12 g of potassium hydroxide. The procedure necessitates a temperature of 60 °C and entails the chemical reaction between triglycerides and alcohols, yielding the formation of glycerol and fatty acids. The collection and filtration processes are employed to separate the Mahua seed methyl ester from the glycerol in the by-products. Transesterification is a commonly employed method in the utilization of vegetable oils in CI engines due to its ability to decrease oil viscosity without causing substantial adverse effects on engine performance or durability. The present study evaluated the experimental inquiry conducted on a CI engine, which was fueled with Mahua biodiesel and various diesel mixes containing alumina nano additive. The engine underwent analysis using several test fuels. The performance and emission characteristics of Mahua biodiesel blends, consisting of 10%, 20%, 30%, 40%, and 100% concentrations, were evaluated under various load circumstances. The experimental results indicate that the fuel blend consisting of 30% Mahua biodiesel and 70% diesel (Referred to as B30) exhibited satisfactory performance and tailpipe emissions when compared to other mixes of biodiesel. The production of nano blended biodiesel involved a mixture including 70% diesel, 30% Mahua biodiesel, and varying concentrations of nano Al_2O_3 at 10, 40, and 70 ppm. Table 1 presents the measured parameters of diesel and Mahua biodiesel.

Biodiesel exhibits a greater viscosity and density in comparison to conventional diesel fuel, with a discernible 5% increase in density attributed to its unique chemical composition. The flash point of this substance exceeds 64 °C, rendering it a viable and secure substitute for diesel fuel. The decision to transition to Mahua biodiesel in IC engines is a judicious one,

Table 1: Properties of diesel and Mahua biodiesel.

Properties	Diesel	Mahua biodiesel
Density	832 kg/m^3	874 kg/m^3
Viscosity @ 40 °C	3.2 cst	4.72 cst
Flash point	82 °C	135 °C
Fire point	92 °C	147 °C
Calorific value	43400 J/kg	44400 J/kg
Cetane number	48	55

primarily owing to its elevated flash point.

Experimental setup

The study employed a TAFE engine and an Eddy current dynamometer to obtain accurate measurements of engine power. The emissions of NO_x, HC, and CO were measured in real-time using an exhaust gas analyzer and smoke meter that were calibrated using reference gases. Prior to each measurement, a zero-point adjustment was implemented. The utilization of alumina nanoparticles has been found to enhance the stability of fuel over prolonged durations. Specifically, the addition of a surfactant concentration of 2% has been observed to further augment this stability (Figure 1).

Nano additives in IC engines are beneficial due to their low melting point, large surface area, efficient heat and mass transfer, exceptional thermal conductivity, high energy content, and resistance to oxidation. Alumina in biodiesel increases the carbon-oxygen ratio, speeding combustion and improving fuel efficiency. Ultrasonication distributes alumina in Mahua biodiesel at 10, 40, and 70 ppm. Figure 1 shows alumina scanning electron microscopy analysis. Figure 2 shows the alumina Energy dispersive X-ray spectrum. Carbon, oxygen, and aluminum make up 8.92%, 48.83%, and 42.24% of the sample, respectively. Table 2 lists alumina's chemicals. ISO-8178 requires a five-mode cycle at 1500 rpm. The Engine Data Acquisition and Control System is essential for performance data collection.

The SAJ Fuel Consumption Meter is utilized for the purpose of quantifying the amount of fuel consumed by an engine, whereas the AVL DI Gas 444 gas analyzer is employed to gather data on emissions. The utilization of a U-tube manometer facilitates the measurement of the mass flow rate of air entering an inlet, hence enabling the formulation of mathematical formulas. Experiments are performed under diverse situations, encompassing engine speed and load, while maintaining consistent temperature and air conditions. The experimental configuration is depicted in figure 3, which is readily accessible.

Mahua biodiesel and its diesel blends with Al_2O_3 nano addition were tested in a single-cylinder CI engine. Diesel (D100), Mahua biodiesel (B100), 90% diesel (B10), 80% diesel (B20), 70% diesel (B30), and 60% diesel (B40) were tested at varied load situations. Nano blended biodiesel was made with 70% diesel, 30% Mahua biodiesel included 10, 40, and 70 ppm nano Al_2O_3 are analyzed.

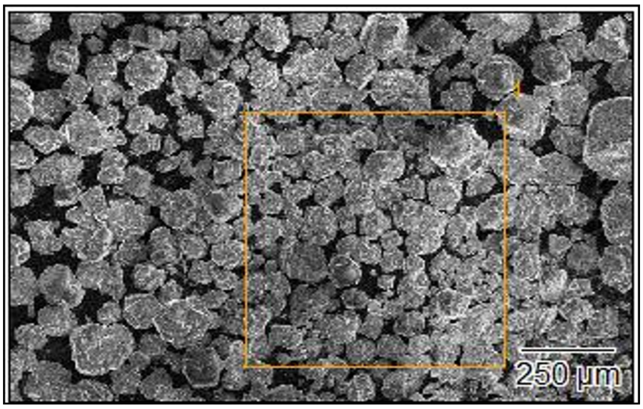

Figure 1: Scanning electron microscopy analysis of alumina.

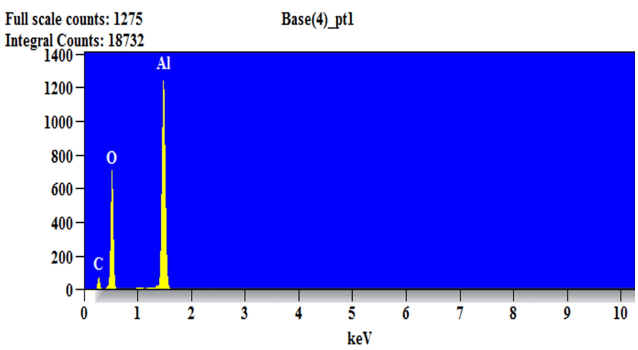

Figure 2: Energy dispersive X-ray spectrum of alumina.

Table 2: Chemical composition of alumina.

	C	O	Al
Alumina	8.92	48.83	42.24

Results and Discussion

Research studies are done on both Mahua biodiesel and diesel to see how well they run on diesel engines. These studies look at things like BTE and BSFC. The BSFC is tested to see how well the engine works with biodiesel, which have different amounts of calories and specific gravities. The ratio between the mass flow rate of the fuel being tested and the real power is the BSFC.

Brake thermal efficiency

The data demonstrates that the BTE improves as the load level increases. The performance of Mahua biodiesel blends with nano-additives was evaluated. Except for the B30 blend, which has equal BTE to diesel due to excellent oxygen availability to increase combustion efficiency, biodiesel's lower heating value as a result of fuel-bound oxygen and higher density greatly lowers BTE. This is the case even if the B30 blends has a higher density. Figure 4 shows how diesel and Mahua biodiesel blends compare in terms of their thermal efficiency as

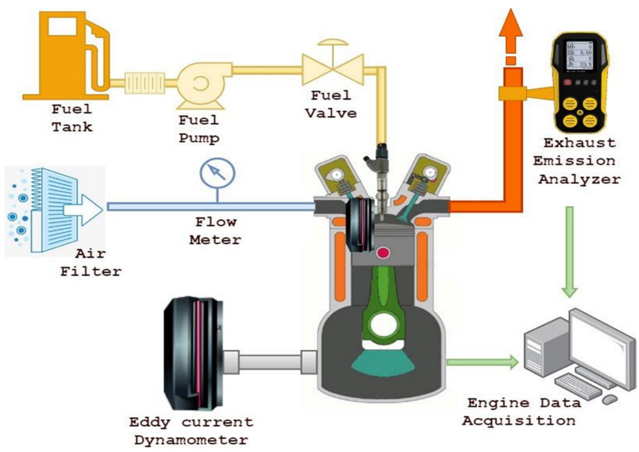

Figure 3: Experimental setup of single cylinder diesel engine.

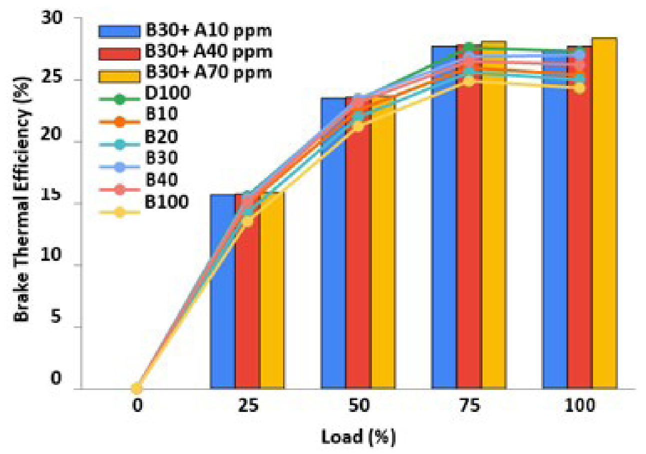

Figure 4: BTE of alumina included Mahua biodiesel blend.

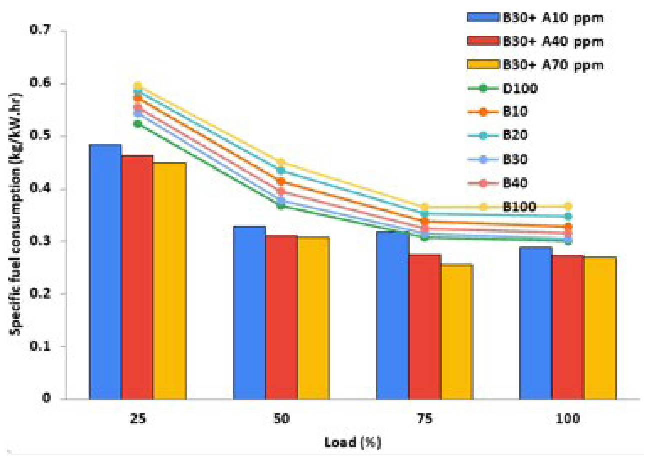

Figure 5: BSFC of alumina included Mahua biodiesel blend.

brake fluid. Combustion is catalyzed by nano additives, which results in increased efficiency. The burning of fuel particles was boosted by the addition of alumina nano additives. Therefore, blends including nano additives exhibited a greater BTE than blends containing Mahua biodiesel. When compared to a base diesel mix, the BTE was raised by 0.3%, 1.5%, and 3.94%, respectively, when Mahua biodiesel with 10, 40, and 70 ppm of alumina was used. The BTE is depicted in figure 4 for Mahua biodiesel blends that incorporate alumina.

Brake specific fuel consumption

The measurement of BSFC is utilized to assess the efficiency of a combustion engine. The metric used to express this relationship is grams per kilowatt-hour, which represents the ratio between the mass flow rate of fuel and the power output of the engine. The mass flow of gasoline is determined by the torque and speed of the engine. The measurement of hourly fuel consumption, also known as fuel mass flow rate, involves monitoring the changes in fuel mass over a specific period of time. The fuel mass flow is influenced by the increase in engine speed and torque. The product of torque and speed yields the power output of an engine. Therefore, BSFC can be mathematically represented as a function of engine speed and torque. The BSFC exhibited a decrease as the load increased from no load to full load. The rise in combustion temperature caused by loading leads to a decrease in both ignition delay and BSFC. The demand for Mahua biodiesel and its blends is larger than that of diesel due to their elevated viscosity. Figure 5 illustrates the BSFC of blends comprising diesel and Mahua biodiesel. The inclusion of alumina nano additive at concentrations of 10, 40, and 70 ppm resulted in a reduction in BSFC when compared to the utilization of Mahua biodiesel (B30 mix). The utilization of nano additives, through the process of atomization, has been found to significantly decrease BSFC by enhancing catalytic activity. In comparison to the standard diesel fuel, the utilization of Mahua biodiesel containing 10 ppm, 40 ppm, and 70 ppm alumina resulted in a reduction in BSFC by 4%, 9%, and 10.63% respectively. Figure 5 illustrates the BSFC of blends using alumina-included Mahua biodiesel.

Carbon monoxide

From a condition of no load to one of full load, there is an increase in CO. The primary cause of CO formation is an inadequate supply of air and fuel for the combustion process. Due to the presence of oxygen in biodiesel, which speeds up the fuel's combustion, diesel produces higher levels of CO emissions than biodiesel and biodiesel blends do. When operating at higher loads, the quantity of fuel is greater than the air supply, which results in increased levels of CO emissions. The levels of CO emissions produced by diesel and Mahua biodiesel blends are illustrated in figure 6. When compared to base diesel, CO emissions were reduced by up to 41%, 46%, and 50%, respectively, when alumina concentrations of 10 ppm, 40 ppm, and 70 ppm were incorporated in Mahua biodiesel, respectively. The CO emissions caused by alumina, including those caused by biodiesel blends, are depicted in figure 6.

Hydrocarbon emission

Diesel, which is made of hydrogen and carbon, is responsible for the formation of HCs at a higher rate than biodiesel and biodiesel blends, which show lower levels of HC formation when compared to diesel. When compared to conditions with no load, full load conditions result in higher HC emissions. Because the amount of gasoline that is injected into the cylinder is more when the load is higher, emissions are greater at higher loads than they are at lower loads. Figure 7 presents a visual representation of the HC emissions produced by die-

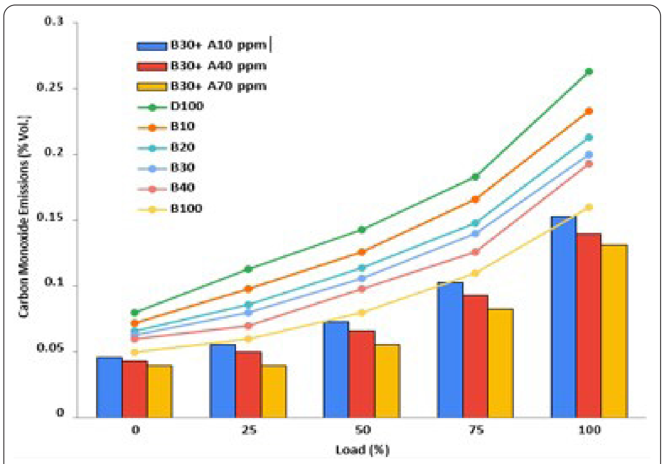

Figure 6: CO emissions of alumina included Mahua biodiesel blend.

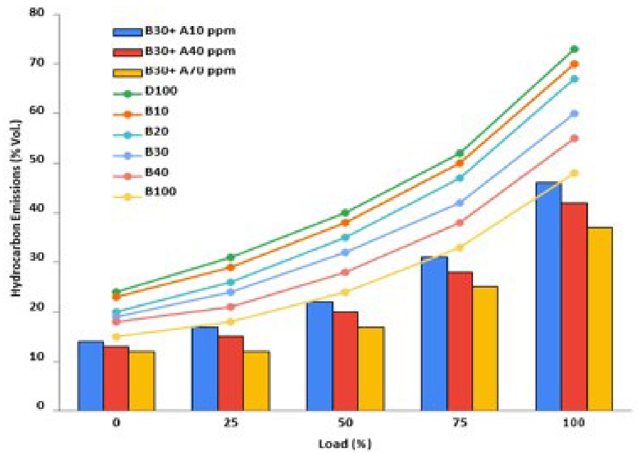

Figure 7: HC emissions of alumina included Mahua biodiesel blend.

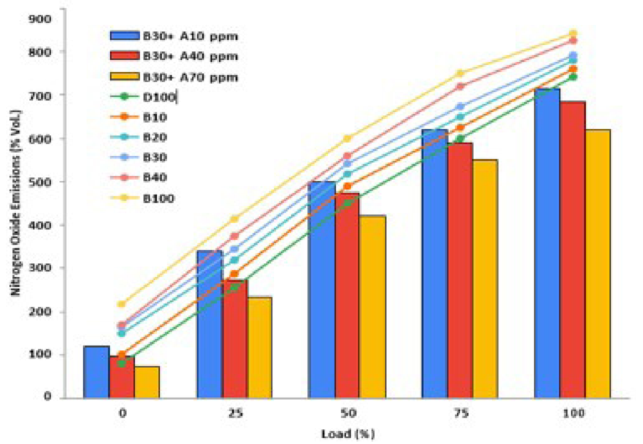

Figure 8: NOx emissions of alumina included Mahua biodiesel blend.

sel and Mahua biodiesel blends. With the addition of nano additives, the atomization of biodiesel is improved, and the combustion rate is increased, leading to a reduction in the emission of HCs. When compared to diesel, HC emissions were reduced by as much as 36%, 42%, and 49% when alumina concentrations of 10 ppm, 40 ppm, and 70 ppm were incorporated in the Mahua biodiesel, respectively. The HC emissions of alumina, including those from Mahua biodiesel blends, are displayed in figure 7.

Nitrogen oxide emissions

The emissions of NO_x exhibit an upward trend when the operating condition transitions from no load to full load. An observable phenomenon is that an increase in load leads to a corresponding increase in combustion temperature, which subsequently results in elevated levels of NO_x emissions. In contrast to diesel fuel, biodiesel exhibits a higher propensity for NO_x emissions due to its increased oxygen content. Figure 8 illustrates the levels of NO_x emissions resulting from the combustion of diesel and biodiesel mixtures. The use of nano additives has been found to raise the surface volume ratio, accelerate the combustion rate, and improve the heat transfer rate, resulting in a reduction of NO_x emissions. The emission of NO_x was observed to decrease by 3.6%, 7.6%, and 16.3% when alumina concentrations of 10 ppm, 40 ppm, and 70 ppm were added to Mahua biodiesel, respectively, in comparison to the emissions from base diesel. Figure 8 illustrates the levels of NO_x emissions emitted by alumina, encompassing biodiesel mixtures.

Conclusion

The depletion of fossil fuels is occurring at an accelerated rate. In addition, these resources have the potential to contribute to air and water pollution, habitat degradation, and the emission of greenhouse gases, so exacerbating climate change. The experimental investigation was assessed in a single cylinder, CI engine fueled with Mahua biodiesel and its diesel blends with alumina nano additive. The utilization of biofuels holds promise as a feasible substitute for fossil fuels in the context of automobile applications. The experimental investigation involved testing different fuel blends, namely diesel (D100), Mahua biodiesel (B100), a blend of 10% biodiesel and 90% diesel (B10), a blend of 20% biodiesel and 80% diesel (B20), a blend of 70% biodiesel and 30% diesel (B30), and a blend of 40% biodiesel and 60% diesel (B40), under various load conditions. In comparison to alternative biodiesel blends, the utilization of a 30% Mahua biodiesel and 70% diesel blend (Referred to as B30) exhibited favorable performance characteristics and shown reduced levels of emissions at the exhaust. The utilization of a 70-ppm alumina nano additive in the biodiesel mixture has been found to enhance thermal efficiency and reduce emissions. This can be attributed to the beneficial effects of nanoparticles on fuel atomization, leading to improved combustion characteristics. In contrast to diesel fuel, the BTE and BSFC of biodiesel containing a mixture of 70 ppm alumina nanoparticles exhibited a 4% increase and a 10% decrease, respectively. The Mahua biodiesel blended with biodiesel exhibited a reduction of 49%, 50%, and 16% in HC, CO, and NO_x emissions, respectively, compared to the basic fuel. The utilization of nano mixed Mahua biodiesel has been identified as a more viable alternative energy source for unmodified CI engines.

Acknowledgements

None.

Conflict of Interest

None.

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