Sustainability Utilizing biodiesel and aluminium oxide (Al2O3) nanoparticles to improve CI engine performance and emission analysis

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Abstract

In this work, 500 PPM concentration of Al_2O_3 nanoparticles (40 nm size) are utilized as fuel additives in a 4-stroke, single-cylinder, water-cooled CI engine along with the biodiesel forms B10, B20, and B30 produced from rice bran. The engine operates at constant speed of 1500 RPM, 0 kW to 3.5 kW load, and 17.5:1 mm compression ratio. For this experimental effort, nano fuel is prepared by the ultrasonication technique.Using a magnetic stirrer, eight different samples of nano-added mixed fuels, including B10$Al_2O_3$500, B20 $Al_2O_3$500 and B30$Al_2O_3$500, have been synthesized. All RBME biofuel nano additive fuel blends were analyzed on CI engine characteristics, and the results were then compared to the characteristics of neat diesel fuel. The primary goal of this research is to strengthen the engine's performance and combustion attributes while degrading NO_X, CO_2, CO, and HC exhaust emissions into the environment.In this research, BSFC, BTE, and EGT engine performance indicators enhanced in contrast to neat diesel although NOx, CO, CO_2, and HC exhaust emission dropped by 25.45%, 58%, 3.52%, and 18.12%, respectively. However, this experimental study's use of all types of blended fuels resulted in a modest improvement in loudness. Diesel engine performance and combustion characteristics significantly increase during using Al_2O_3 nano addition in biodiesel blend fuel.

Keywords: Exhaust emissions, Nanoparticles, Performance of CI engine, Biodiesel

Introduction

Due to growing global energy consumption, there is a corresponding rise in the price of fossil fuels. Depending on its characteristics, biodiesel is a reliable alternative and environmentally friendly energy source that the researcher uses. In experiments conducted, it is examined how to extract oil from both edible and inedible sources, how to produce biofuel by transesterification, and how to utilize a catalyst to eliminate fatty acids.[1]Three stages are involved in the production of biodiesel, including the manufacture of the fuel using algae, non-edible oil sources, and oil seeds sources. Alcohol is employed for better results because it is feasible like diesel fuel, even though biodiesel is made from waste, which is an inedible source. [2,3,4]On the other side, some nations advance to the 3rd generation, where biofuel is made from algae using modified crop plants. [5,6]The biodiesel transesterification process is used to reduce these problems. Homogeneous catalysts such as alkaline catalysis NaOH, KOH and acid catalysis H_2SO_4, HCl or heterogeneous catalysts such as enzymes, earth metals, and titanium silicate are used in the process. The produced biofuel has inferior characteristics such as high viscosity and low uncertainty, higher density, which are antithetic to the diesel fuel. [7,8] Metal oxide nanoparticles (CuO, SiO_2, ZnO, TiO_2, Al_2O_3, CoO_2, etc.) and non-metallic oxide nanoparticles (GO, carbon nanotube) are two types of nanoparticles that are used to improve the physiochemical properties of fuel and their catalytic properties to regulate the combustion chamber's temperature. [9,10]Results from the diesel butanol blend (B20) with 30, 50, and 100 PPM Al_2O_3 nanoparticles were carried out by ayad et al. They reported that the fuel has good stability after mixing the nanoparticle into B20. There was a 42.71%, 37.46%, and 12.37% decrease in CO, HC, and NO_X exhaust emissions, correspondingly, as well as an improvement in combustion properties including cylinder pressure and exhaust gas temperature. [9]When using crude RBME with concentrations of B10, B20, and B40, Chhabra et alstudy .'s team[11] studied the performance and emission parameters of a 4-stroke water-cooled diesel engine at a range of compression ratios from 12 to 18 and up to 3.75 kW load. According to their findings, B10 and B20 fuel blends at the 14 CRs enhanced BTE by a maximum of 21.86% when compared with pure diesel fuel. In this investigation, the BSFC for B40 at 14 CRs at full load (3.75 kW) was increased by 10.25%. At maximum load, CO_2 and NOx emissions were only substantially decreased, and at zero kW load, HC emissions were comparable to those of diesel fuel. Dhamodaran and others.performed their experimental work and compared the RBME, neem, and cottonseed biodiesels' performance, combustion, ignition, and exhaust emission properties to neat diesel fuel. When the diesel engine is operating at full load, they use 20% biodiesel (B20). At maximum load, they discovered that using RBME, neem, and cottonseed biodiesel decreased BTE by 3.45%, 10.34%, and 13.79%, respectively, and improved EGT by 7.81%, 5.65%, and 3.12%.[12]

Experimental Setup

An agricultural diesel engine with four strokes and a single cylinder that runs at 1500 RPM and a fixed compression ratio of 17.5:1 mm is employed in this experimental investigation. Table 1 lists all the engine's specs that were used for this experimental study. The Bharat-produced engine has a water-cooling system. Electric heater coupled filaments ranging from 0 kW to 3.5 kW are connected to a DC generator with a variation in load of 0.5 kW, and a water flow calorimeter is utilised for water flow measurement, as part of the load study. A variety of temperatures, including the temperature of the water input, the two distinct water outlet temperatures for the engine and calorimeter, the temperature of the exhaust gas outlet, and the ambient temperature, are all measured using different types of temperature measuring sensors.The NO_X, CO_2, CO, CO, HC, and (lambda) from exhaust emission are measured by the Airvisor 5 gas analyzer device, and engine noise is measured by the use of Sound level metre datalogger software. The ratio between the amount of oxygen present in the combustion chamber and the total amount needed for ideal combustion is represented by the (lambda) value. For the manufacture of the fuel, an electronic balance, 230 Volt/150 Watts magnetic stirrer, and an ultrasonicator instrument are used to weigh the 750 mg/L and 1500 mg/L nanoparticles, mix/heat the nano additive biodiesel mixed fuel, and disperse the nanoparticles in the fuel, respectively.

Table-1

Specifications of the test diesel engine

Item	Value
Engine Manufacturer	Bharat
Bore × Stroke	(87.5 × 110) mm.
Number of Cylinders	1
Engine Displacement	661 cc
Compression Ratio	17.5:1 mm
Rated Power	3.5 kW

Materials And Techniques

Indians prefer rice over any other crop. In 2022, India will produce 168 million tonnes of rice, making it the second-largest producer behind China. Following the extraction of oil from rice crop waste, rice bran biodiesel is created. It has a higher viscosity, reduced volatility, and a lower calorific value than diesel fuel once the rice bran oil has been extracted. Triglycerides and alcohol were combined to improve the characteristics, and rice bran oil was treated with alkyl catalysis to remove the acids, producing biodiesel in the form of methyl esters. The transesterification process is the name given to this entire procedure.When rice bran oil is combined with conventional diesel in quantities of 10%, 20%, and 30% to create the B10, B20, and B30 fuel blends, rice bran biodiesel (RBME) has a lower viscosity, greater volatility, and higher calorific content. Al_2O_3 nanoparticle concentrations of 500 PPM was combined in the biodiesel blend fuel. For 1.5 hours, the blended fuel is mixed using a magnetic stirrer running at 1500 RPM.The ultrasonication procedure is used to disperse the nanoparticles in the fuel. The Al_2O_3 nanoparticles' enzymatic impact and temperature - dependent characteristics improved the fuel's qualities. Table 2 displays the nanoparticles' specifications. Ostwald's viscometer, bomb calorimeter, hydrometer, and Pensky-Martens closed cup tester equipment are used to measure, respectively, the fuel's kinematic viscosity at 40 OC, heating value, density at 15^{O}C, and flashpoint. Table 3 displays the characterizations of the mixed fuel in accordance with ASTM standards.

Table -2

Item	Value
Molecular Formula	Al_2O_3
Melting Point	2055^0C
Bulk Density	0.5 g/cm^3
Particle Size	50 nm
Purity	99.9%
Molecular Weight	101.96 g/mol

Table 3 Properties of fuel.

Properties/fuel	D100 (Neat)	B10	B20	B30	$RB10Al_20_3$	$RB20Al_20_3$	$RB30Al_20_3$	Standard
Flash point (^{0}C)	74	185	188	76	83	85	87	ASTM D-93
Kinematic Viscosity, 40^{0}C	3.8	3.31	3.79	4.9	3.63	3.25	3.01	ASTM 7042
Density, Kg/m^3, 15^{0}C	837	831	835	852	836	855	890	ASTM D-1298
Heating Value (MJ/Kg)	44.0	45.43	45.90	44.05	45.9	46.14	46.63	ASTM D240

The Research results and Discussion

Performance Analysis of the CI Engine-

BSFC-specific analysis

Based on a diesel engine's specific fuel usage, this factor evaluates the engine's performance. When the engine is operating under various loads, it is calculated when 1 litre of fuel is burned in 1 hour. At all loads, the BSFC improves with the addition of the nanoparticles, but at high loads, the fuel consumption for the D100Al500 fuel is lowest when the nanoparticles are combined with the pure diesel (3.5 kW).At 1.5kW, 2.5kW, and 3.5kW, respectively, RB10Al500, RB30Al500, and RB20Al500 showed the highest enhancements of 31.42%, 33.8%, and 46%. This occurs because introducing Al_2O_3 nanoparticles into the biodiesel improves its atomization, enabling optimal combustion, and raising the temperature in the combustion chamber. This results in a higher oxygen content being available to the biodiesel. The rate of heat emission also increases as a result of this occurrence.

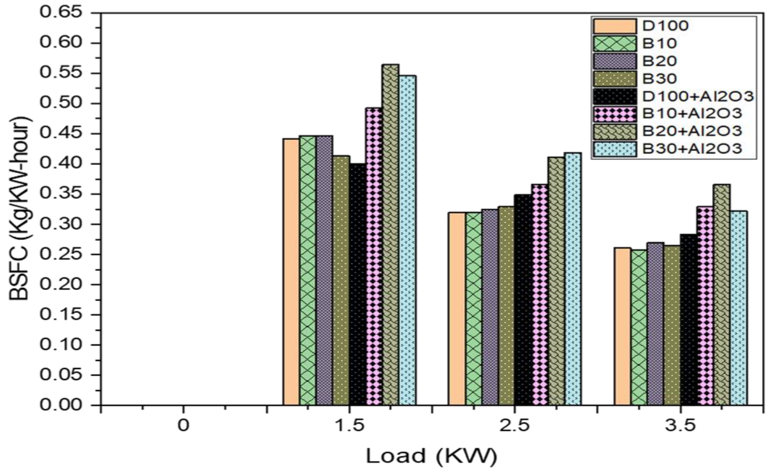

Figure 1 Graph for BSFC versus loads.

Brake Thermal efficiency-

The load or braking power to fuel energy supplied ratio determines an engine's BTE. It can be used to define how much an engine works mechanically as well as the maximum load multiplication of heat energy flow for combustion. The improved combustion characteristics of the combined fuel were responsible for the effective outcome. Biodiesel's combustion properties are improved when nanoparticles are added, which raises BTE. In comparison to tidy diesel (D100) at 1.5 kW load, the result for B30 fuel is 8.69% higher. However, as biodiesel load and concentration rise, a decline in BTE is seen.

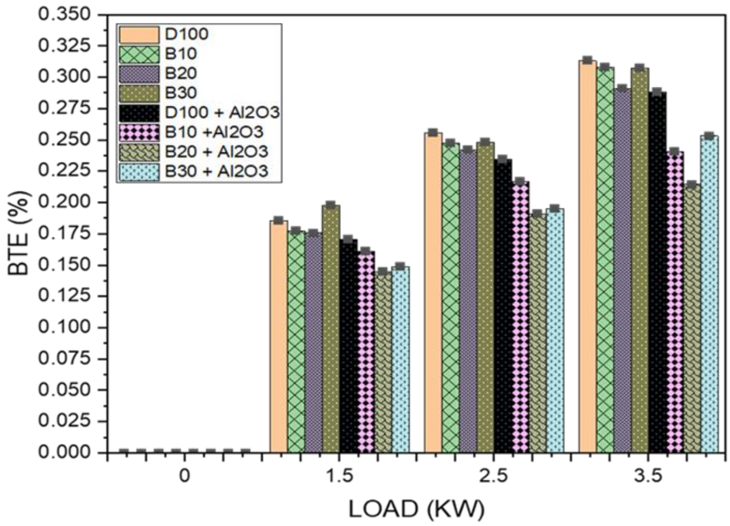

Figure 2 Graph for BTE versus Loads.

Analysis on Exhaust Emissions-

The primary goal of this research is to reduce the engine's significant damaging exhaust emissions.

NO_X Emissions-

Global warming is caused by NOX since it directly depletes the ozone layer. In this experimental investigation, the maximum reduction in NOx from the exhaust is 25.45%. This is a result of the combustion chamber having an excess of oxygen and having favourable temperature conditions.Al_2O_3 nanoparticles' thermal conductivity causes the temperature to drop, which lowers the NO_X content for 0, 1.5, 2.5, and 3.5 kW loads, with values that are correspondingly 23.27%, 18.56%, 12.52%, and 10.98% lower than neat diesel for RB30Al500, RB10Al500, RB20AL500, and RB30 (D100).

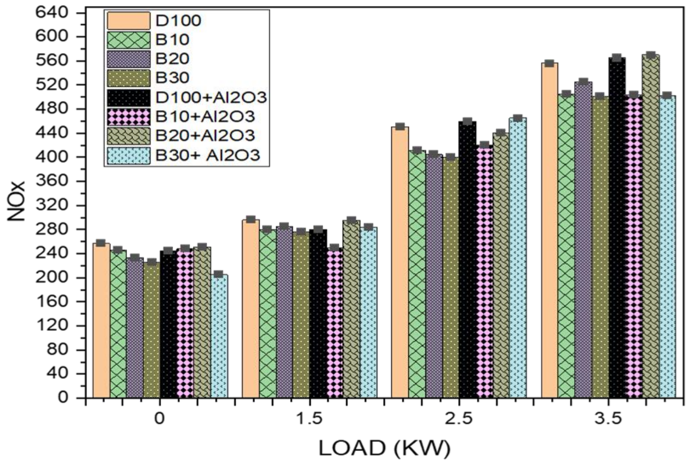

Figure 3 Graph for NO_X versus loads.

CO Emission-

At all loads, the RBME with Al_2O_3 emits a different amount of CO. CO concentration in the exhaust was caused by the use of nano additive blended fuel. Comparing neat diesel to all-biodiesel blended fuel with Al_2O_3 nanoparticles, the CO concentration rises 58% after use.This is due to the higher flash point temperature, which prolongs the time it takes for fuel to burn, and the higher oxygen content, which causes the fuel to burn a little more quickly and raise combustion chamber temperature. The neat Diesel in this experiment emits the same amount of CO_2 for fuel types B10, B20, B30, D100Al500, and RB10Al500 at 1.5 kW and 2.5 kW, respectively (D100).

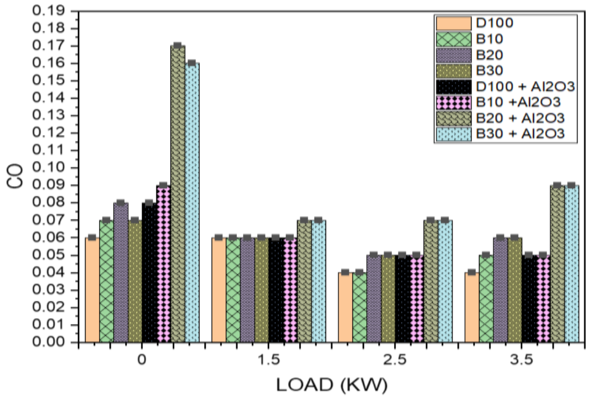

Figure 4 Graph for CO emission versus Loads.

Conclusion-

Very significant improvements in performance and emissions were made utilising alumina nanoparticles in combination with rice bran biodiesel. The sulphur level from the exhaust emission was very low due to the simplicity of obtaining rice bran and the characteristics of aluminium oxide nanoparticles. Following is a summary of the series of actions taken throughout the experiment and the results attained:

• The outcomes of this experimental study for exhaust emissions were improved. All fuel concentrations at 1.5 kW were found to emit the increase amount of CO as neat diesel, with the exception of RB20Al500 and RB30Al500. At 2.5 kW load, it was also equivalent for RB10.

• The NO_X content dropped for RB30Al500, RB10Al500, RB30, and RB30 at 0 kW, 1.5 kW, 2.5 kW, and 3.5 kW, respectively, by 23.27%, 18.56%, 12.52%, and 10.98%.

• In compared to neat diesel (D100), there was an increase in BSFC of 46% for RB20Al500 at 3.5 kW load and an increase in BTE of 8.69% for RB30 at 1.5 kW load when Al_2O_3 nanoparticles and rice bran biodiesel were added to the fuel.

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