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Examining How the Addition of AL2O3 and CEO2 Nanoparticles to Used Cooking Oil May Affect Engine Operation, Combustion, and Emissions

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Abstract: The objective of this study is to compare the combustion, emissions, and engine performance of two different modified fuels. The oxygenated nanoparticles (CeO2 and Al2O3) were homogeneously mixed into B20 with an ultra sonicator at a specific ratio of 50,100 ppm to explore the potential of nanoparticles as a flexible booster in physiochemical properties of biodiesel. The generated nanoparticle fuel samples are then put to the CRDI VCR engine at various loads (3,6,9,12 kg): B20+50 Al2O3, B20+100 Al2O3, B20+50 CeO2, B20+100 CeO2. The different nano fuel's engine capabilities, combustion, and emissions are then contrasted with biodiesel, diesel, and one another. Performance-wise, BTE was 11.39% higher and SFC was 13.74% lower than B20 for B20+ 50 Al2O3 at high load. The cylinder pressure and heat release rate for B20+50 Al2O3 are respectively 16.77% and 21.48% greater at full load than for B20. In terms of hazardous emissions, B20+50 Al2O3 reduced CO emissions by 15.06% compared to B20, while B20+50 CeO2 reduced HC emissions by 50% compared to diesel at peak load. Additionally, at engine peak loads, B20+50 CeO2 Reduces NOx by 18.29% compared to B20. The findings suggest using nano fuel as a diesel oil replacement fuel.

Keywords: Biodiesel, Cerium oxide (CeO_2), Aluminium oxide (Al_2O_3), Brake thermal efficiency, Specific fuel consumption, Emissions.

I. INTRODUCTION

The increased population demand is causing a significant rise in the usage of fossil fuels. Oil-based fuel use has increased as a result. The universe's primary source of energy is this. Fossil fuel shortages affect several nations negatively economically. Contrarily, fossil fuels cause air pollution by releasing emissions including CO2, HC, and NOX, which is why many researchers are exploring for alternative fuels to reduce our reliance on fossil fuels. Biofuels have become the best alternative fuel, according to recent studies.

Because biodiesel is a renewable fuel with characteristics similar to those of diesel, it can be utilised in diesel engines without requiring any design changes. Biofuels are produced in a similar way greater NOX emissions, better engine performance, and lower UHC and PM emissions.

The oxidation stability and cold flow characteristics of biodiesel are poor. The chemical makeup of biofuel is what causes the greater NOX levels, poor oxidation stability, and poor cold flow qualities. The chemical composition of biofuel and diesel barely differs.

Biodiesel is created using a range of basic materials, including plants, animal fats, algae, and microorganisms. Methyl ester, which is what biodiesel is, is often made from free fatty acids found in various natural resources. Biofuels offer a number of advantageous qualities, some of which are listed below, making them potential replacements for fossil fuels.

1) Diesel and biofuel are similar in terms of their physical and chemical characteristics.
2) It might be locally accessible in several feedstock types. It might be created using fatty waste. Despite the production of biofuel, solid waste management may still happen in other ways.

Because it is miscible with diesel

a) It may be used with a blend of diesel; it is compatible to use in a diesel engine without modifying the design of a diesel engine.
b) it is biodegradable, sustainable, non-toxic, and environmentally beneficial.

Biofuel provides more oxygen during fuel combustion because it is an oxygenated fuel. Oxygen molecules support fuel combustion. so that gasoline is burned properly inside the combustion chamber.

II. MATERIALS AND METHODOLOGY

Waste cooking oil is used cooking oil that is no longer suitable for use in cooking since it has lost its ability to properly prepare food. Recycling cooking oil repeatedly could be harmful to people's health. Because of this, sewage from used cooking is disposed of, perhaps contributing to water contamination problems. Cooking oil waste disposal is a serious issue. Researchers are looking to recycle used cooking oil as a supporting biofuel with diesel fuels for C.I. to keep the realities like waste oil and water pollution issues in mind. In order to eliminate different cooking food residues, waste cooking oil was collected from different restaurants in Greater Noida (Uttar Pradesh) and filtered for this study. WCO was also assessed in light of its post-filtration physiochemical traits. Waste cooking oil has a higher density and viscosity than diesel fuel, which could cause issues with fuel atomization and injection within the combustion chamber. To prepare the biofuel, the transesterification procedure was chosen. Root biofuel is heated to 100 degrees Celsius to remove moisture before to transesterification, and then it is cooled to 60 degrees. This is known as a preparatory procedure. To prepare biofuel, transesterification is currently being done. Waste cooking oil from the transesterification process was put into a flask with CH3OH and KOH catalyst (1%w/w). A 6.5:1 molar ratio of biofuel to CH3OH was employed. The reaction flask is heated to between 60 and 70 OC, and 400 rpm is applied. It took the entire process two hours to calm down. As shown in fug 4, biofuel methyl ester and glycerin layer were produced. Due to its higher density than glycerol, biofuel oil is extracted from it. The next stage involves washing the acquired biofuel with warm water that has been heated to between 80 and 90 degrees Celsius. Heated water would carry away a substantial fat residue, which would then settle down as depicted in fig. 5. Further To remove moisture, biofuel is heated to 100 oC one more. Biofuel is produced using this method without the use of moisture or residuals. Then, new biofuel samples like B20 (20% WCME+80%diesel), B20+50 PPM (CeO2), B20+100 PPM (CeO2), B20+ 50 PPM (Al2O3), and B2020+ 100 PPM (Al2O3) are created.

A. *Nano Particle Preparation*

Al2O3 and CeO2 nanoparticles were used for the experimental studies. According to fig. 6, alumina nanopowder was transported from D54, Site4, Surajpur, Greater Noida, UP201308.CeO2 was obtained from mincometsal simplified solutions Konena Agrahara in Bangalore, 560017. The good physicochemical characteristics of both nanoparticles are listed in table no. 3 below. The morphology of Al2O3 and CeO2 nanoparticles was examined in DTU using XRD and SEM. Figures 8, 9, 10, and 11 depict the XRD and SEM images of both nanoparticles (Al2O3 and CeO2), respectively. Al2O3 and CeO2 nanoparticles' average sizes range from 10 to 20 nm and 10 to 30 nm, respectively. The preferred approach for determining size composition, crystal structure, sample purity, morphology, and other properties directly is XRD and SEM. Al2O3 and CeO2, which were purchased, are suitable nanoparticles to utilise with biodiesel, according to XRD and SEM photos.

B. *Nano-Biofuel Blend Preparation*

Al2O3 and CeO2 nanoparticles were independently introduced to the B20 (waste cooking + diesel) biofuel in this experimental study. For 1 kilogramme of biodiesel fuel, 50 ppm and 100 ppm of nanoparticles are added. An ultrasonicator was used to combine nanoparticles with waste cooking biofuel for 30 minutes at a frequency of 40 kHz and 160 watts. An ultrasonicator prevents the nanoparticle from aggregating. To fully dissolve the homogenous nanoparticles in the mixture, the Ultrasonicator employs high frequency for one hour. B20+50 PPM (CeO2), B20+100 PPM (CeO2), B20+ 50 PPM (Al2O3), and B20+ 100 PPM (Al2O3) are recently developed nano additive fuels.

III. RESULT AND DISCUSSION

A. *Engine Performance Characteristics*

1) *Specific Fuel Consumption(SFC)*

SFC is defined as the amount of fuel used per minute to generate mechanical power on the engine's shaft. Fuel qualities including viscosity, density, calorific value, and density are all connected to fuel consumption. Higher cetane numbers are directly correlated with higher fuel density, but higher viscosity gasoline has a lower calorific value. Poor atomization, air-fuel mixing, air-fuel dispersion, swirl ratio, and penetration caused by higher viscosity have an adverse effect on combustion characteristics and engine performance. The study noticed that B20 exhibits greater BSFC than diesel under different load levels; this may be due to the fuel's reduced calorific value. Different amounts of AhO3 nanoparticles were introduced to B20 to improve the physio-chemical characteristics of the fuel that eventually reduced BSFC. BSFC significantly decreased after the ignition of B20+30AhO3, B20+50AhO3, and B20+100AhO3, respectively, contrasted B20 by 2.6%, 5.13, and 9.24%. Bi2O3 nanoparticle blended fuel was calculated to have a lower minimum BSFC than B20.

The heating value of fuel is improved by the expansion of nanoparticles of Bi_2O_3, which results in a reduction in fuel consumption for the same amount of power output on the engine shaft. Additionally, it has been observed that the addition of CeO_2 and MgO nanoparticles to WCO biodiesel fuel reduces specific fuel consumption when compared to that of unadulterated diesel. This is because the increased surface-to-volume proportion and decreased ignition delay result in better ignition and reduced fuel usage. Options utilising nanoparticles do reduce overall energy use, although results may vary depending on the type of nanoparticle applied. Due to the highly developed combustion characteristic of the fuel as engine load increases, the SFC decreases with an increase in load. SFC steadily dropped as engine power grew without changing the engine's architecture. . By focusing on the presence of several features, such as kinematic viscosity, heating value, flash point, density, and cetane number, the thermodynamics of the combustion process, engine performance, and emission characteristics were evaluated. The dispersion of AhO3 metallic nanoparticles in diesel methanol mixture enhances engine performance due to their increased conductivity, higher surface-to-volume ratio, oxygen expansion, and catalytic properties. According to experiment evaluation, 100 ppm AhO3 nanoparticles additive fuel resulted in a 3.6% increase in BTE. Additionally, because nanomolecules have a high surface-to-volume ratio, they participate in the blending of air and fuel to a greater extent , which speeds up the pace at which the fuel and air combination vaporises and increases the spread of fuel droplets and air-fuel injection. To promote better combustion and effective fuel energy conversion, nanoparticles are used. The primary factor contributing to the increase in power to the additional energy created on the cylinder is the higher surface to volume ratio of nanoparticles, which leads to enhanced heat transfer. Nano additions accelerate heat release and increase cylinder peak pressure by shortening the time it takes for the fuel to ignite and burn [25,26, 38]. Because CERIA nanoparticles' impetus conduct creates the thermodynamic of ignition measure, which in turn has an effect on engine performance and discharges, the expansion of CERIA nanoparticles in used cooking oil (B20+CERIA45) further developed BTE, requiring an imperative increase as high as 10.5% in comparison to base diesel fuel at full engine load. AhO3 nanoparticles have a high surface-to-volume ratio and strong thermal conductivity, which enhances the temperature and pressure of combustion as well as the air-fuel mixing, dispersion, and penetration of the fuel. Engine performance was improved by improved combustion characteristics, which also reduced ignition latency. For all load settings, the BTE of the B20+AhO3100 mix is the highest compared to D100 and B20. For fuels including nanoparticle additives, such as B20+25AhO3, B20+50AhO3, and B20+100AhO3 at full load and 1500 rpm, a rise in BTE of 3.56%, 7.51%, and 13.53% was observed. The addition of AI_2O_3 increases the test fuel samples' calorific value. Due to their high surface-to-volume ratio and strong thermal conductivity, AI_2O_3 nanoparticles enhance the temperature and pressure of combustion as well as the air-fuel mixing, dispersion, penetration, and evaporation of fuel. Engine performance was improved by improved combustion characteristics, which also reduced ignition latency. Due to the fuel's higher viscosity and lower calorific content, B20 has the lowest BTE. Higher viscosity is the reason for inefficient fuel atomization, inefficient air-fuel mixing, and inefficient combustion. The efficiency with which fuel energy is converted into practical work may be lacking. The lowest BTE of B20 may have a valid explanation in this.

B. Combustion Characteristics Of Diesel Engine

1) Cylinder Pressure

In order to analyse combustion behaviour in the combustion chamber and assess engine performance, the cylinder pressure parameter is necessary. It was found that as the engine load was raised, engine pressure also increased. Low engine load (60%) causes less fuel to be injected, which lower ignition flame temperature causes, lengthening the ignition delay duration. With a higher load, the combustion cylinder received more charge injection, which led to an increase in cylinder surface and combustion flame temperature and a reduction in the ignition delay time. Compared to neat biofuels, the ignition delay time caused by nanoparticle expansion is more constrained. The main factor influencing the length of the ignition delay period is the variety of fuel feedstock, nanoparticles, and their quantity inside the burning chamber. In addition, the length of the ignition delay period was related to the ignition temperature and pressure, pre-ignition energy transfer, convection, and radiation to the surrounding area. The connection between cylinder pressure and crank angle for a number of tested fuels under full load is shown in Figure 10. The findings suggested that as engine load grew, cylinder pressure increased, suggesting that at higher engine loads, more petrol was injected and consumed.

2) Net Heat Release Rate

The rate at which heat is released by the combustion flame is defined as HRR (the heat produced by the combustion blend at a specific angle). The heat release rates for the fuel tested at full load at each angle of the paddle. Diesel ignition delays were longer than that of HRRs for both biodiesels.

The HRR is based on the amount and quality of the air/fuel mixture, the value of fuel heating, and the duration of the time-consuming delay inside the CI engine's already-existing combustion chamber. When compared to diesel, which has the lowest air-fuel mixing rate and the highest viscosity and air result, it significantly lowers the mixing ratio and increases the quantity of oxygen. Due to its higher heat value, diesel fuel will produce a longer ignition delay in the CI engine and an increase in the HRR inside the fuel cell. The fuel's rate of heat transfer was accelerated by the addition of nanoparticles. Higher thermal conductivity and a reactive surface assist the fuel in quickly reaching autoignition temperature.

C. Emission Characteristics

1) Carbon Monoxide emission

If the combustion cycle is not sufficiently oxygenated and there is sufficient fuel for burning inside the engine, carbon monoxide will be produced. Unburned fuel and CO result from a lack of oxygen necessary to convert carbon to CO_2. The main causes of carbon monoxide production include inadequate oxygen levels, poor mixing, locally rich fuel, incomplete combustion, and these factors. Harmful emissions from internal combustion engines include CO, CO_2, HC, NOx, smoke capacity, and PM [44]. When biodiesel is blended with diesel, hazardous pollutants such CO, HC, and PM are reduced. how CO emissions decreased for all fuel samples as engine load increased. The experiment does, however, show that CO emissions increased at full load. At all engine loads, CO emissions were noticeably lower for B20 than diesel. O_2 molecules are part of the molecular structure of biofuels (WCO has a 13.6% weight O_2 concentration), which causes complete combustion to occur at a higher temperature. The effects of adding AhO3 nanoparticles to diesel fuel on fuel atomization, air-fuel mixing, flame spread, fuel spray, swirl ratio, fuel dispersion, fuel penetration, and ignition flame characteristics were examined by the researcher.

2) Hydrocarbon Emission

Incomplete combustion of the fuel particles causes more HC to be created. Because biodiesel has a higher oxygen content and less carbon and hydrogen than ordinary diesel fuel, it emits fewer HCs. Engine load increased along with HC emissions. When under a heavy load, more fuel is fed into the combustion chamber, starting a rich mixture of air and fuel. There won't be enough oxygen for combustion in a rich mixture because more fuel will come into contact with hot air, slowing the rate at which fuel droplets evaporate. The inclusion of nanoparticles to petrol mixtures dramatically lowers hydrocarbon emissions. As a catalyst, nanoparticles accelerated the oxidation of hydrocarbons and brought about complete combustion. The secondary atomization of the Nano additives speeds up HC oxidation and reduces HC emissions. The smaller size of nanoparticles led to an improvement in fuel atomization in fuel injectors. Additionally, optimal combustion and increased fuel-air blending rates reduce HC discharges. Reduced HC outflows are caused by the scattering of nanoparticles with fuel, which improves fuel atomization and spray. This leads to proper air-fuel mixing, an acceleration of the air-fuel heat transfer rate, and more developed burning. Additionally, CeO_2 nanoparticles have served as experts in oxidation to hasten the oxidisation of charge, reducing harmful emissions including CO and HC emissions and smoke opacity.

As a result of proper atomization, air-fuel mixing, and air-fuel dispersion occurring inside combustion and AhO3 acting as an oxygen donor in the combustion process, which are metallic nanoparticles with a greater surface-to-volume ratio, complete combustion took place inside the combustion chamber. Less HC emissions after complete combustion. Diesel produces a 62% greater level of high HC than B20 at a higher load. But when compared to B20 at full load, B20+AhO3100 produces around 28.94% more emissions. The average predicted HC emissions under all circumstances are 11.8%, 22.36%, 28.94%, and B20+25AhO3, B20+50AhO3, and B20 +100AhO3 compared to B20 at full load conditions, respectively.

3) Nitrogen Oxide Emissions

Additionally significant elements in the formation of NOx during fuel combustion are temperature and high activation energy. Because of the high temperature's high activation energy, atmospheric nitrogen is changed into nitrogen oxides. Generally speaking, the increased oxygen in biodiesel leads to high temperatures during combustion, which produces a significant amount of NOx. For all of the tested fuels, NOX emissions gradually increased as engine load increased.

Higher load causes the cylinder to get more fuel injection, which raises the temperature of the combustion flame. At a greater temperature, NOX is generated. At full load, the NOX emissions from B20 are more than those from D100. More O_2 is present in B20, supporting full combustion at higher temperatures. At full engine load, B20+100AhO3 exhibits a maximum increase in NOX emissions of up to 13.63% as compared to B20.

IV. CONCLUSION

The current study looked into the technical viability of using waste cooking palm and waste cooking sunflower biodiesel as alternative biodiesel fuels to run a CRDI VCR diesel engine under various engine load conditions. With a fixed CR = 14, IP = 60 MPa, and IT = 30 obTDC, the CI engine's parameters were examined at a constant engine speed of 1500 rpm, and the results were compared to those of the diesel fuel engine. In the current experimental investigation, it is examined how adding Al2O3 to the biodiesel B20 (WCPM 10%+ WCSM 10%+ Diesel 80%) will affect its performance, combustion, and emission characteristics. The following is a summary of the findings based on the experimental study. In comparison to pure diesel and B20, the SFC of the fuel containing nanoparticle additions (B20+100AhO3) fell and increased dramatically under all load circumstances.

The peak pressure of biofuels with Al2O3 nanoparticles added to them increased, with B20+100AhO3 having the highest peak pressure in comparison to B20 and diesel. In addition to that, adding nanoparticles to B20 speeds up the CI engine's rate of heat release. Compared to B20 and diesel fuel, the fuel sample (B20+100AhO3) had the highest heat release rate.

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