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A COMPREHENSIVE DISCUSSION ON THE IMPACT OF CUO NANOPARTICLES AS FUEL ADDITIVES IN BIODIESEL

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Abstract

Presently, there is a substantial worldwide need to replace fossil fuels with renewable energy sources. The greenhouse effect is considered to be one of the adverse outcomes of fossil fuels, resulting in an increase in global temperatures. Biodiesel is a feasible alternative to fossil fuels that can be produced from a variety of organic sources. Researchers are investigating the application of nano-materials to power systems in order to alter the properties of fuel in compression chambers. The objective of this project is to replace diesel fuel with a blend of diesel and biodiesel produced from waste cooking oil (WCO) by a catalytic transesterification reaction (CTR). CTR converts WCO into methyl esters by gradually adding a tiny quantity of alcohol over one hour at a reaction temperature of 65 °C. A fuel blend will be formulated to fuel a four-stroke direct injection engine, comprising 40% diesel, 60% biodiesel, and various quantities of CuO nano-material. The engine will maintain a consistent speed of 1400 revolutions per minute (rpm) without the need for forced induction, and it will experience varying amounts of workload. The experiment involved testing different fuel mixtures, including pure diesel, B40 (60% biodiesel and 40% diesel), 50b40 (60% biodiesel, 40% diesel, and 50 mg of CuO), 100B40 (60% biodiesel, 40% diesel, and 100 mg of CuO), 150 (60% biodiesel, 40% diesel, and 150 mg of CuO), and pure diesel. An investigation has been carried out to examine the impact of copper oxide on the performance of engines and the release of emissions. The experiment's results suggest that diesel engines can function with varying mixtures of fuel, biodiesel, and CuO nano-material, while keeping the same operating parameters. The collected data indicates a 10% enhancement in brake thermal efficiency, an 11.6% reduction in exhaust temperature, and a 6.66% drop in brake specific fuel consumption.

Keyword: Internal combustion engine; emissions; biodiesel; nanoparticles; waste cooking oil; direct injection diesel engine.

Introduction

In recent times, there has been a surge in the exploration for novel and sustainable fuel sources. The utilization of sunflower and soybean biodiesel, in combination with silver thiocyanate nano-material, is employed to adjust the BTE (brake thermal efficiency). This follows the consensus reached by numerous countries and institutions to embrace global practices aimed at safeguarding the environment through the reduction of emissions and fossil fuel consumption. They were focused on improving the efficiency of combustion systems, particularly in the context of internal combustion engines. In order to accomplish this objective, all research institutions aimed to optimize the generation of alternative fuels that may be utilized in internal combustion engines without requiring any fundamental modifications to the existing fuel systems.

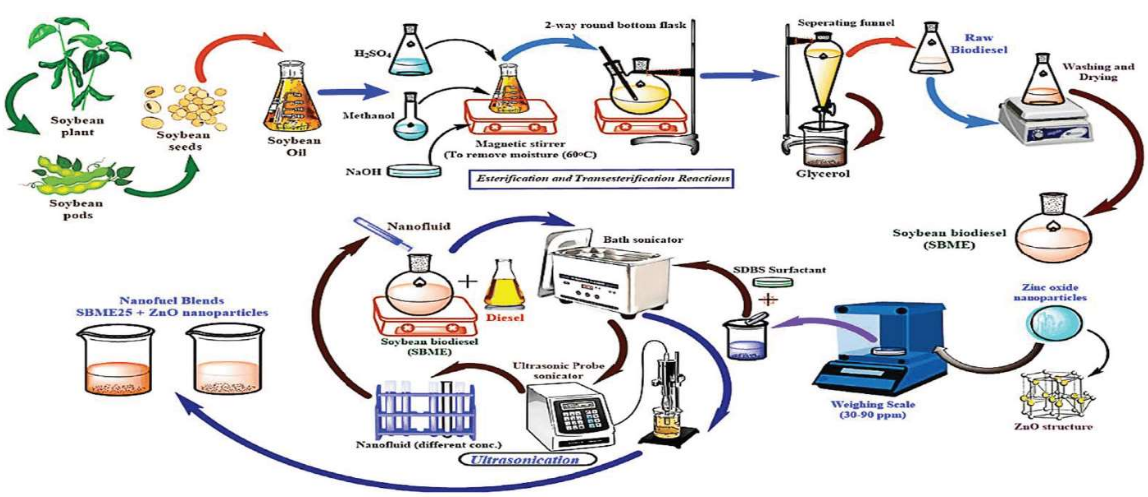
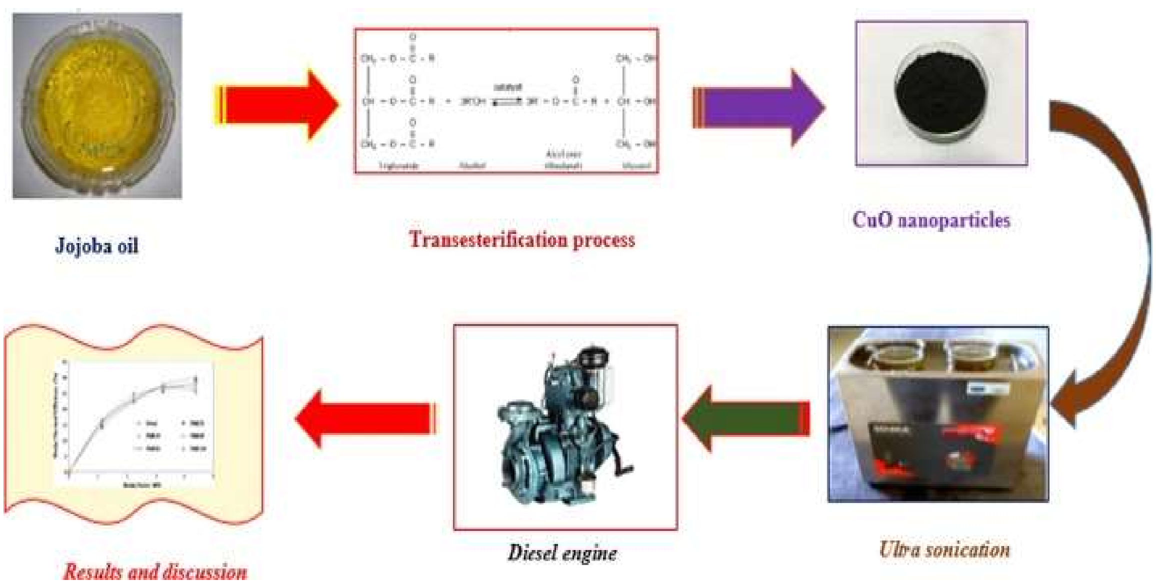


Figure 1: Effects of Nano-Additives Added to Diesel-Biodiesel Fuel

Key areas of research in this field were the conversion of wasted food oils into biofuel, the growth and collection of algae, and the fermentation of agricultural waste. The researchers utilized advanced mathematical and numerical techniques to optimize the performance of internal combustion engine systems by incorporating nanometric materials technology. Fossil fuels are classified as a non-renewable energy resource. The price of fossil fuels fluctuates in response to global political and economic issues and can be utilized as a tool for exerting political influence on any nation. Emissions generated by engines powered by fossil fuels have a detrimental impact on the environment. It is necessary to decrease these emissions in order to comply with environmental regulations. Scientists have been researching the utilization of nano-materials in conjunction with biodiesel for direct injection engines. The findings indicate that the utilization of nano-material in combination with biodiesel has altered the engine properties [1-5].

Figure 2: Effect of CuO nanoparticles concentration on the performance and emission characteristics of the diesel

There are several accepted results. When using B25 fuel with 50 ppm alumina nano-



material, the engine's performance improved by 4.8%. Additionally, the fuel consumption rate (BSFC) decreased by 8.5%. The concentrations of HC, CO, and smoke were reduced by 36%, 20%, and 44% correspondingly. Utilizing graphene oxide (GO) in combination with waste cooking biodiesel (WCBD) at concentrations of 100 and 200 parts per million (ppm) results in reduced specific fuel consumption (BSFC) for WCBD100GO and WCBD200GO at rates of 3% and 7% kilograms per kilowatt-hour (kg/kWh) respectively. Despite a 7% and 16% reduction in exhaust gas temperature, there was a corresponding gain in Brake Thermal Efficiency (BTE) of 4% and 1.2%, respectively.

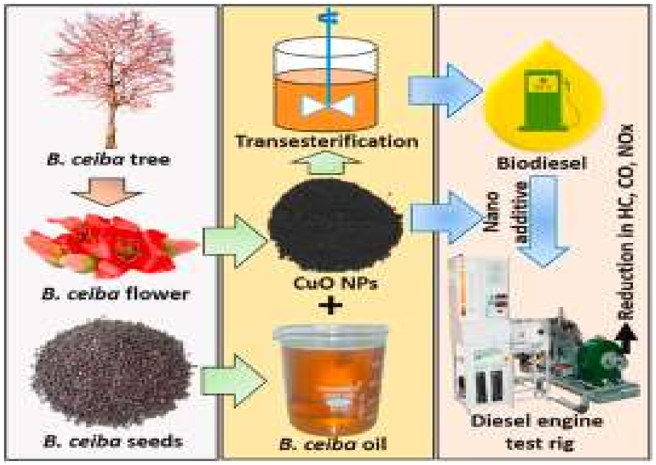


Figure 3: Green synthesis of copper oxide nanoparticles using the Bombax ceiba plant

Applying CeO_2 nanoparticles to neat palm oil methyl ester and diesel blends at concentrations of 10, 20, and 30 nm decreases brake specific fuel consumption (BSFC) and increases brake thermal efficiency (BTE). Nevertheless, the concentrations of carbon monoxide (CO) and hydrocarbons (HC) experienced a reduction of 3.6% and 4.2% respectively. The utilization of CeO_2nano-material resulted in a reduction of NOx and smoke emissions by 3.8% and 6.4% respectively. The addition of 100 parts per million (ppm) of titanium dioxide (TiO_2) to Pongamia biodiesel fuel results in a reduction of hydrocarbon (HC), smoke, nitrogen oxide (NOx), and carbon monoxide (CO) concentrations by 2.1%, 2.7%, 3.8%, and 1.9% respectively. The utilization of carbon nanotubes and graphene nano sheets at a concentration of 100 ppm in a diesel engine running on WCO B20 resulted in an 8% and 19% increase in Brake Thermal Efficiency (BTE), respectively. The smoke is reduced by 28% and 54% respectively, while CO is reduced by 27% and 47% respectively, and NOx is reduced by 22% and 44% respectively. By introducing 100 parts per million (ppm) of copper oxide nanoparticles measuring 10 and 20 nanometers, the performance of a direct injection diesel engine running on mahua biodiesel with natural aspiration and constant speed was enhanced. Specifically, the brake specific fuel consumption (BSFC) increased by 1.3%, while the brake thermal efficiency (BTE) improved by 0.7% [6-11].

Resulting in a 4.9% increase in CO emissions, a 3.9% increase in NOx emissions, a 5.6% increase in HC emissions, and a 2.8% increase in smoke emissions. Utilizing Sr@ZnO nanoparticles at concentrations of 30, 60, and 90 ppm in a blend of 20% Ricinus communis biodiesel and 80% diesel fuel in a common rail direct injection engine operating at a constant speed results in a significant improvement in heat release rate (HRR), brake thermal efficiency (BTE), and cylinder pressure. Specifically, the HRR, BTE, and cylinder pressure rise by 24.35%, 20.83%, and 9.55%, respectively. The ID, BSFC, smoke, CD, HC, CO, and CO_2 were reduced by 20.64%, 20.07%, 27.90%, 14.5%, 26.81%, 47.63%, and 34.9%, respectively.

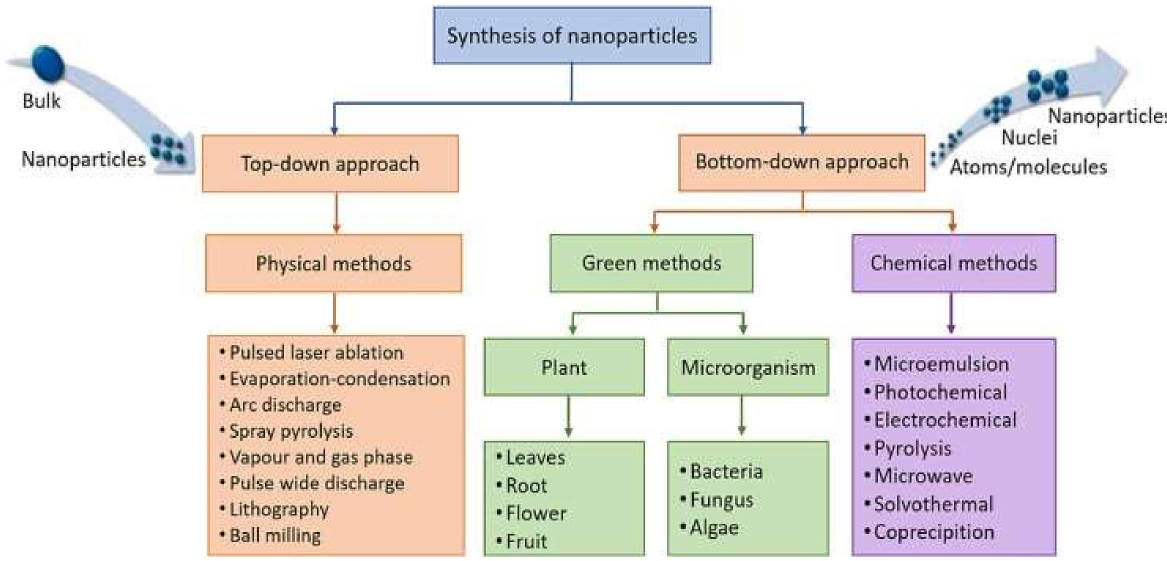


Figure 4: Impact of nanoparticle-based fuel additives on biodiesel combustion

The concentration of NOx experienced a modest increase. An increase in Brake Specific Fuel Consumption (BSFC) and Brake Thermal Efficiency (BTE) can be achieved by incorporating cerium oxide (CeO2) nano-material with biodiesel in a Direct Injection (DI) engine. Additionally, this combination leads to a decrease in the quantity of soot, nitrogen oxides (NOx), smoke opacity, carbon monoxide (CO), and hydrocarbons (HC). The utilization of a nanoscale silver thiocyanate configuration in a diesel engine, powered by a blend of 50% diesel and 50% biodiesel, enhances both engine efficiency and pollution levels. Utilizing 25, 50, and 75 nanoparticles of cerium-coated zinc oxide (Ce-ZnO) in diesel-soybean biodiesel blends results in a 20.66% increase in brake thermal efficiency (BTE) and an 18.1% increase in heat release rate (HRR) in a diesel engine. Resulting in a decrease of carbon monoxide (CO) emissions by 30%, smoke emissions by 18.7%, and hydrocarbon (HC) emissions by 21.5%. By incorporating a 50% blend of diesel and biodiesel, along with the addition of 200 ppm of silver thiocyanate (AgSCN) and 4% hydrogen peroxide (H2O2), there is a significant 27.16% rise in BTE (brake thermal efficiency) [12-22].

The addition of (CeO2) nano-material at concentrations of 25, 50, 75, and 100 ppm to a diesel engine running on biodiesel blends enhances the Brake Thermal Efficiency (BTE), decreases emissions, and lowers Brake Specific Fuel Consumption (BSFC). Utilizing a titanium dioxide (TiO2) metal-based compound in a diesel engine enhances the maximum cylinder pressure heat release rate (HRR), resulting in improved engine performance and combustion. The addition of TiO2 to a diesel engine results in an increase in both the heating value and Cetane number. The introduction of graphene oxide (GO) nano-material into a diesel engine powered by biodiesel blends leads to a decrease in carbon monoxide (CO), unburned hydrocarbons (UHCs), and brake specific fuel consumption (BSFC), despite an elevation in nitrogen oxide (NOX) levels. Utilizing carbon coated aluminum (Al@C) nano-material in biodiesel blends results in decreased BSFC, CO, and NOx levels in a running diesel engine. Consequently, engineers, scientists, and researchers are seeking a suitable substitute for diesel that may be utilized in direct injection diesel engines.

In this instance, WCO is generated using a Catalytic transesterification reaction. Following the production of biodiesel, a washing process is conducted to remove pollutants and alter the properties of the biodiesel, such as density and viscosity. Various combinations of diesel, biodiesel, and CuO nano-material will be used to create different percentage blends. The diesel engine will operate at a consistent speed of 1400 rpm while experiencing different levels of workload. A hydraulic dynamometer is used to connect the engine, enabling the operator to easily change the loads. The effects of utilizing various fuel mixtures will be assessed by comparing them to the properties of diesel fuel. This will be done by evaluating brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), exhaust temperature (Tex), and emissions rate.

Experimental Setup and Procedure

Engine and Test Rig Installation

The test equipment is equipped with a diesel engine model (ZS1125NM) connected to a hydraulic dynamometer of type ATE-160 LC [4, 52]. The dynamometer allows the operator to adjust the loads while operating the engine. Flow control valves are connected to the test rig, which was designed to enable the operator to select and modify the fuel type while the engine was running. The test rig is equipped with a fueling mechanism that allows the operator to accurately measure the amount of fuel consumed within a specific time period. The GASBOARD-5020 gas analyzer device is connected to a test rig to monitor emissions, including CO, CO2, O2, UNHC, and NOx. The GASBOARD-6010 model is a device used to measure the soot rate in exhaust gases[54]. The RPM indicator is utilized to measure the rotational speed of the engine. Thermocouples are utilized to gauge the temperatures of cooling water, oil, and inlet/exhaust.

Internal combustion engine and dynamometer Technical details

The hydraulic dynamometer model ATE-160 LC is equipped with a load cell that has digital torque indicator. This load cell is connected to the engine. The load cell has a capacity that varies from 0 to 350 kg (or 0 to 1050 N-m) [55]. The calibration length of the lever arm is 0.7645 meters, as indicated by references [56, 57]. The wheel and sensor have 60 teeth, and the connection is fixed on the shaft. Hydraulic and water absorption properties [23-25].

Characteristics of nanoparticles

Nanomaterial research is attracting increasing attention due to its unique characteristics, such as enhanced electrical conductivity, hardness, and ductility. The enhanced hardness and strength of metals and alloys, the improved luminescence of semiconductors, the greater formability of ceramics, and their utilization in magnetic storage media are all elements that contribute to their respective applications. The conversion of solar energy, the study of electronic systems, and the acceleration of chemical reactions. Copper oxide is one of the crucial transition metal oxides. Copper oxide is essential in the manufacturing of high-temperature superconductors, as well as in applications involving photoconductivity and photothermal effects. Copper oxide nanoparticles were produced using the sonochemical technique. The methods used include sol-gel technique performed at room temperature, one-step solid state reaction technique, electrochemical approach, and co-implantation of metal and oxygen ions.

The size and shape of copper oxide were determined using a transmission electron microscope (TEM) with an accelerating voltage of 200 kV on a JEOL JEM-2100. Additionally, a high-resolution transmission electron microscope was used to obtain more detailed images. Experiments were done using wide-angle X-ray diffraction and small-angle capability XRD techniques at an accelerating voltage of 200kV. A X-ray diffraction (XRD) analysis was conducted throughout a 2 theta range of 20 to 80, with a minimum step size of 0.001 in 2 theta units. The XRD pattern was obtained at a wavelength of 1.54614 angstroms (Ka).

Production of Biodiesel

In production process, WCO is converted into biodiesel by a catalytic transesterification mechanism. Catalyst (NaOH), methanol, and used waste cooking oil are the reaction's components. The reaction needs 60 minutes withmixing conditions at 65 °C. The oil will be burnt if reaction temperature becomes more than 65 °C therefore, the reaction must be under thermal control. The electric mixer is programmed to operate until the reaction temperature reaches 65 °C. If reaction temperature rises, the mixer will be turned off. At a volumetric oil to methanol ratio of 1:1.2035 and a catalyst weight concentration of.65%, the highest biodiesel production yield of 93% is achieved. The reaction produces glycerol, biodiesel, fat, and dirt. For a good separation, glycerol needs to be separated for roughly 12 hours.

Biodiesel washing process was performed after biodiesel production process washing process takes place. Biodiesel must be cleaned of fats and other impuritiesusing a washing procedure. With a volumetric ratio of 1:1, hot water is employed at 100 °C. Washing process needs a special technique for avoiding foaming of biodiesel so washing mixer cannot run continuously. The mixer is controlled to run for 5 seconds and stop for 3 seconds in each washing process. After 1 minute, biodiesel and water need time to be separated from each other. Repeating this process about 3:5 times for ensuring good washing. Biodiesel may turn into soap if washing process takes longtime more than 1 minute. Biodiesel physical properties change during washing like density and color. The decrease in density is benefit for fueling system. By the end of washing process, the biodiesel is ready for using in diesel engine. For storing biodiesel, it is crucial to maintain it in sealed containers away from air to prevent oxidation [26-30].

Comparison between diesel and biodiesel were performed after production of biodiesel should have physical and thermal characteristic as diesel to ensure suitable replacement for diesel in fueling system and combustion chamber. The same fueling system that was made to use diesel fuel should be used for biodiesel. Large difference in any characteristic between biodiesel and diesel leads to certain problem in feeding, combustion chamber and exhaust gas analysis.

Within biodiesel blends, this decrease will lead to a corresponding rise in the specific fuel consumption. Biodiesel exhibits a higher kinematic viscosity compared to diesel, which might impede the flow of fuel via the fueling system. Biodiesel has a higher density than diesel, which results in inadequate vaporization in the combustion chamber. Nevertheless, biodiesel has a higher cetane number compared to diesel, resulting in an extended delay in the occurrence of explosions.

The Mixing Process was conducted to achieve a uniform mixture of biodiesel and diesel fuel. Diesel and biodiesel were mixed in the desired proportion to a mixing container equipped with a mixing motor. The process of achieving thorough mixing may require a duration of one hour. Inadequate blending results in the stratification of different densities. Incorporating nano-material into the fuel blend requires expertise. A uniform dispersion of nanomaterial inside the blend is preferred. The name of the blend should accurately represent its entire makeup. For instance, the notation D60 B40 N 100 represents a fuel mixture containing 60% pure diesel, 40% biodiesel, and 100 milligrams of nanomaterial per liter. Once the mixing process is complete, the blend is prepared for use in the engine for testing purposes.

The running process for the engine was accomplished following the mixing process. It is imperative to initiate the engine using diesel fuel and allow it to run for a little while initially. The fuel system control valves are utilized to alternate between different fuel blends. Once the fueling system is switched to mix, the operator should wait briefly to let the blend to enter the fueling system. The operator should provide sufficient time for the new mix to fully integrate into the fueling lines and fuel filter. Prior to conducting the measurement process, the operator should allow the engine to stabilize for a few minutes until it reaches a steady condition.

The measurement process occurs once the system has reached a state of equilibrium. Thermocouples of the k-type are employed to measure the temperature of the incoming air and exhaust gas in air intake and exhaust systems. Graded glass tubes are securely attached to the fuelling control board, allowing the operator to accurately estimate gasoline usage. The operator has the ability to modify loads while the engine is running, thanks to the utilization of a hydraulic dynamometer that is connected to the engine. A load cell is attached to a dynamometer in order to display the load on a digital screen. Gas analyzer and soot analyzer devices are utilized to quantify emission rates of carbon monoxide (CO), carbon dioxide (CO2), oxygen (O2), unburned hydrocarbons (UNHC), and nitrogen oxides (NOx).

There is an error. The thermocouples and gas analyzer that were used are attached to the test rig for analysis. These factors include range, uncertainty, and accuracy. The engine's physical properties might greatly influence the empirical results, potentially resulting in erroneous statistics. Hence, mathematical computations have been performed to guarantee the exactness and correctness of the experimental findings. Equation 1 demonstrates the operational characteristics of the engine and the calculations for estimating uncertainties in emissions [31-36].

Results and Discussions

After running the engine with various blends and measurement methods, different results are collected for each case.

The effect of utilizing copper oxide on brake specific fuel consumption.

BSFC, or Brake Specific Fuel Consumption, is a crucial characteristic that greatly influences engine performance. The term refers to the proportion of power generated by the engine to the amount of gasoline consumed during a certain period. Figure 7 demonstrates a clear inverse relationship between BSFC and load elevation. By comparing diesel with D60 B40 N00, it may be analyzed and evaluated. It has been demonstrated that the specific fuel consumption (BSFC) of pure diesel is lower than that of a blend of 60% diesel, 40% biodiesel, and no additives (D60 B40 N00 BSFC). This is because biodiesel has a higher viscosity and lower heating value.

The addition of CuO nanomaterial causes a drop in BSFC till it becomes lower than the BSFC of pure diesel. The utilization of CuO nanomaterial leads to an increase in the reduction of Brake Specific Fuel Consumption (BSFC). The greatest reduction in Brake Specific Fuel Consumption (BSFC) occurs when comparing pure diesel fuel to a blend of 60% diesel, 40% biodiesel, and 150 parts per million of a nitrogen-based additive. This reduction amounts to 6.66% at a specific power output of kW. This reduction in size renders CuO nanomaterial very suitable for utilization in biodiesel blends as a substitute for diesel in direct injection engines, making it one of the most optimal options available.

The effect of utilizing copper oxide on the thermal efficiency of an engine brake

BTE is considered a vital engine attribute since it quantifies the energy conversion from fuel to power. Figure 8 of the BTE diagram illustrates that the Brake Thermal Efficiency (BTE) increases proportionally with the load due to the occurrence of complete combustion. When comparing the Brake Thermal Efficiency (BTE) of pure diesel fuel with D60 B40 N00 fuel, it is evident that the BTE of D60 B40 N00 is lower than that of pure diesel due to its lower heating value. With the addition of CuO nanoparticles, the efficiency of material BTE steadily increases until it surpasses the efficiency of pure diesel, reaching its highest value at D60 B40 N150. The highest increase in BTE is 10% at a power output of 6 kW. The observed increase in BTE indicates that the addition of kw nanomaterials leads to a modification of BTE. The effect of utilizing copper oxide on the rate of carbon dioxide

Carbon dioxide concentration is a measure of the likelihood of full combustion. Figure 9 displays the concentration of CO_2 for all blends. The graphic demonstrates that when the load increases, the concentration of CO_2 also increases, as a result of the accelerated pace of the combustion reaction. When comparing diesel fuel with blends, it is evident that the concentration of CO_2 falls when using a blend called D60 B40 N00. However, when using a blend including CuO, the concentration of CO_2 begins to climb and eventually surpasses the concentration seen in pure diesel fuel. The highest percentage increase seen between D60 B40 N150 and pure diesel is 11.1% at a power output of 6 kW. By analyzing the rise in Brake Thermal Efficiency (BTE) and the decline in Brake Specific Fuel Consumption (BSFC) and carbon dioxide (CO_2) concentration resulting from the use of CuO, it becomes evident that the more the utilization of CuO nanoparticles, the more efficient the combustion process becomes.

The effect of utilizing copper oxide on the temperature of engine exhaust

Tex refers to the combustion reaction rate in the combustion chamber. Figure 10 depicts the temperature of engine exhaust gasses for different mixtures. The diagram clearly shows that when the load grows, the exhaust gas temperature also increases due to a rise in fuel consumption in the combustion chamber. Through a comparison of diesel Tex and mixes, it has been demonstrated that the use of biodiesel results in a decrease in exhaust temperature compared to pure diesel. As the amount of CuO increases, the exhaust temperature lowers proportionally. The greatest reduction in Tex occurs when comparing pure diesel and D60 B40 N150, with a maximum decrease of 18.4% at a power output of 6 kW. The decrease in exhaust temperature is promising as it reduces the thermal strain on the engine.

The effect of utilizing copper oxide on unburned hydrocarbon.

Incomplete combustion inside the combustion chamber is indicated by a greater rate of unburned hydrocarbons in exhaust gases. Figure 11 clearly demonstrates that as the load increases, there is a drop in hydrocarbons due to the simultaneous increase in brake thermal efficiency (BTE) and carbon dioxide (CO_2) concentration. By conducting a comparison of UBHC rates in diesel fuel and fuel blends, it becomes evident that the utilization of biodiesel and the incorporation of CuO nano-material result in a reduction of UBHC levels. The greatest reduction in UBHC occurs when comparing pure diesel with D60 B40 N150, with a loss of 75% at a power output of 6 kW. This drop pertains to the combustion efficiency, which affects the decision to use CuO with biodiesel in compression ignition engines.

The effect of utilizing copper oxide on the rate of nitrogen oxide.

Various levels of NOx content in relation to exhaust temperature. Several factors influence the rate of nitrogen oxide, such as the reaction temperature (referred to as thermal

NOx), residence duration, and the nitrogen and oxygen content in the fuel. According to the NOx diagram, it is evident that the concentration of NOx in the exhaust gas rises as the load increases due to the elevated reaction temperature. The figure demonstrates a direct decrease in NOx concentration by the utilization of CuO nano-material. This reduction occurs as a result of the drop in exhaust temperature achieved through the utilization of CuO. The reduction of NOx emissions is regarded one of the most important factors that promote the use of CuO nano-material in diesel engines. The greatest reduction in NOx emissions occurs when comparing pure diesel fuel to a blend of 60% diesel, 40% biodiesel, and 150 parts per million of nitrogen compounds. This reduction amounts to 20% and is observed at a power output of 6 kilowatts.

The effect of utilizing copper oxide on the rate of carbon monoxide

The CO concentration in the exhaust gases. The concentration of carbon monoxide (CO) in exhaust gases is an indicator of the rate of incomplete combustion. Inadequate air/fuel ratios and fuel evaporation result in incomplete combustion. Based on the CO graph, it is evident that the concentration of CO increases as the load increases. However, when comparing diesel with blends, it is apparent that the concentration of CO reduces as the amount of CuO in the blends increases. The CO content experiences a maximum reduction of 19% at 6 kW when comparing pure diesel and D60 B40 N150. By reducing the concentrations of both carbon monoxide (CO) and unburned hydrocarbons (UNHC), it is evident that the extent of full combustion is strongly correlated with the percentage of copper oxide (CuO) in the blends, as it increases with higher CuO content.

Conclusion

Through a process known as catalytic transesterification, 93% of the waste cooking oil (WCO) was successfully transformed into biodiesel. The reaction is carried out at a temperature of 65 °C, with a volumetric ratio of methanol to WCO of 0.2035:1.A catalyst with a weight concentration of 65% and a reaction time of 60 minutes. The pricing and production technique for biodiesel are quite uncomplicated. The characteristics of the biodiesel produced are identical to those of pure diesel fuel. Operating direct injection engines with combinations of diesel, biodiesel, and CuO nano-material is a pretty simple task. The subsequent outcomes have been obtained subsequent to operating the engine with different mixtures, without implementing any alterations to the engine, and scrutinizing the data pertaining to loads, fuel consumption, and exhaust composition.

- The utilization of copper oxide at a concentration of 10% leads to an enhancement in brake thermal efficiency.
- The concentration of CO2 increases when copper oxide with a concentration of 11.1% is used.
- The content of CO and UBHC decreases by 19% and 75% respectively when copper oxide is used.
- The utilization of copper oxide at a concentration of 18.4% leads to a reduction in exhaust temperature.
- The use of copper oxide results in a fall in BSFC, with a reduction of around 6.66%.

- The concentration of NOX increases when copper oxide with a 20% concentration is used.

Ultimately, the diesel engine has the capability to function using different combinations of diesel, biodiesel, and copper oxide without the need for any alterations to the engine itself.

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