BIODIESEL FROM WASTE COOKING OIL AND ITS CHARACTERIZATION WITH NANOMATERIALS: ECO-FRIENDLY SYNTHESIS AND EXPERIMENTAL INVESTIGATION FOR PERFORMANCE AND EXHAUST EMISSIONS

Project Reference No.: *47S_BE_2299*

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Keywords

Waste Cooking Oil, Biodiesel, Nanomaterials, Performance, Exhaust Emissions

Introduction

Fossil fuels have historically been the primary source of energy, playing a significant role in human development and advancements, particularly after the Industrial Revolution. However, due to their widespread and relatively unrestrained use, fossil fuel emissions have increased, causing global warming and climate change to occur far more quickly than predicted. Humanity is facing these challenges and is looking toward various renewable energy sources (RES) for power generation, internal combustion engines, mobility and transport, and other sectors. Additionally, there is a search for alternate fuels to reduce dependency on fossil fuels, to meet increasing demands, and to help reduce the emissions causing climate change.

Biodiesel is a renewable and environment-friendly alternative fuel prepared using animal fat, vegetable oil, waste cooking oil, microalgae, and energy plants such as *Jatropha curcas* and sugar cane. It has high biodegradability and low toxicity, and it also has lower combustion exhaust emissions in terms of carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), unburnt hydrocarbons, particulate matter, and smoke due to better combustion of the fuel, which helps in better engine performance. One of the major aspects is its nature of being a drop-in biofuel, meaning no modification is needed in the existing engine design and distribution infrastructure for up to a 20% blend of biodiesel in diesel, i.e. for B20 fuels.

The 28th Conference of the Parties to the UN Framework Convention on Climate Change took place in Dubai, United Arab Emirates, from 30 November to 13 December 2023. For the first time, countries agreed to “transition away from fossil fuels in energy systems.” Governments and industries globally are investing in research and development to accelerate the integration of renewable fuels, fostering a more sustainable and resilient energy landscape for future generations. Repurpose Used Cooking Oil (RUCO), an initiative launched by the Food Safety and Standards Authority of India (FSSAI), aims to create an ecosystem that will enable the collection and conversion of used cooking oil or waste cooking oil (WCO) to biodiesel. The WCO is also not healthy for human consumption as it causes various heart diseases.

Disposing of fat, oil and grease causes major problems with drains and sewers, leading to blockages and polluting streams and rivers. While fat, oil, and grease in liquid form may not seem harmful, they solidify and harden as they cool. This results in them adhering to the inner lining of drainage pipes, restricting wastewater flow and causing blockages. Cleaning these blockages can incur significant costs, reaching lakhs of rupees per year for both businesses and the government.

Objectives

The objectives of the project include:

- To produce low-cost biodiesel from waste cooking oil by the process of transesterification.
- To do cost-effective and eco-friendly synthesis of the nanomaterials using the hydrothermal method.
- To prepare the blend of diesel and biodiesel and further characterization with nanomaterials for experimental analysis.
- To evaluate the properties of the biodiesel blends being produced for comparative analysis.
- To do the sets of experiments to analyze the impact of nanomaterials on the performance and exhaust emissions using the Four Stroke Diesel Engine Test Rig and Emission Analyzer.
- To provide the comparative analysis among the blends produced suggesting the optimum blend of nanomaterials in WCO Biodiesel for improved performance and reduced exhaust emissions.
- To identify the opportunities, challenges and limitations within the Biodiesel from Waste Cooking Oil guiding future research and development efforts.

Methodology

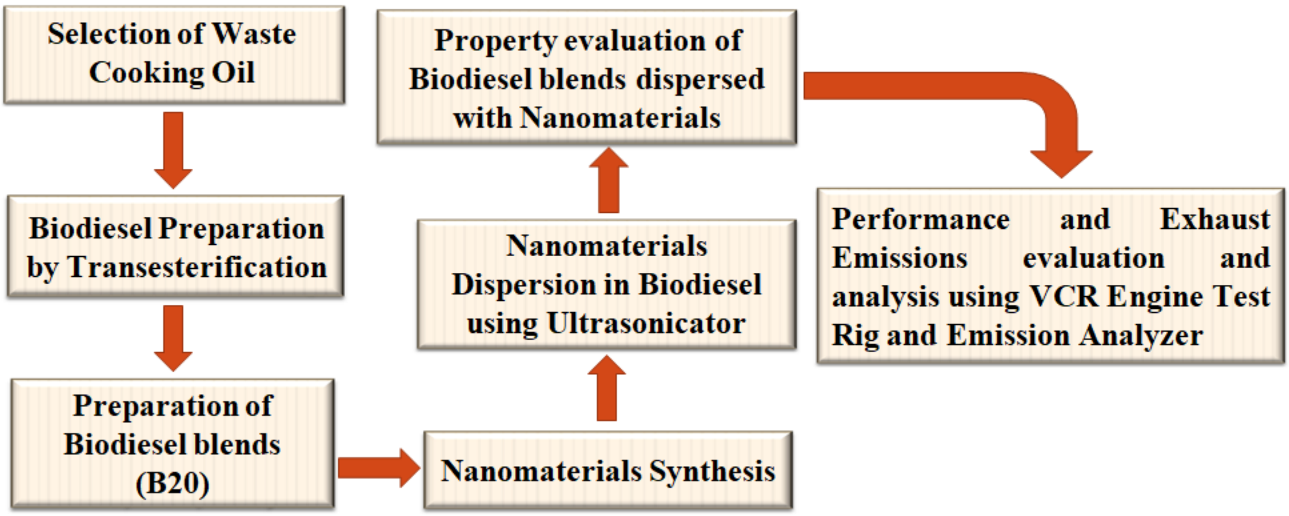

Fig. 1: Overview of Methodology

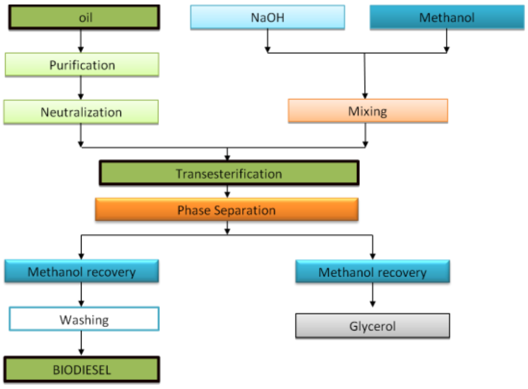

Fig. 2: Transesterification Process

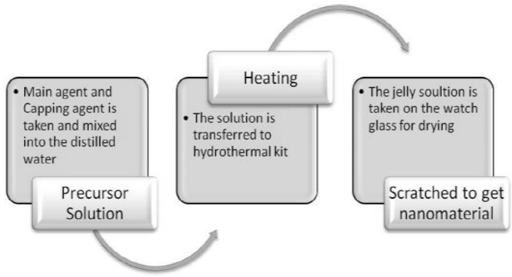

Fig. 3: Hydrothermal Synthesis of Nanomaterials

Experimentation

The experimentation was carried out on a four-stroke diesel engine test rig as shown in Fig. 4.

Fig. 4: Four Stroke Diesel Engine Test rig and Emission Analyzer

Preparation of Biodiesel Blends

The different proportions of biodiesel are given in Table 1.

Table 1: Biodiesel blends details

S. No.	Blends	Description
1.	Diesel	[100% of Diesel]
2.	B20	[20% of Biodiesel, 80% of Diesel]
3.	B20C30	[20% of Biodiesel, 80% of Diesel, 30ppm Calcium Oxide]
4.	B20M30	[20% of Biodiesel, 80% of Diesel, 30ppm Magnesium Oxide]

Results:

Performance and Emission Analysis

Brake thermal efficiency provides information about how the fuel energy is turned into engine output.

Specific fuel consumption (SFC) is a measure of the efficiency with which an engine converts fuel into power or the amount of fuel per unit of power production.

Unburnt hydrocarbons (UHC) refer to the fuel molecules that do not undergo complete combustion in an internal combustion engine or any other combustion process. Instead of being fully oxidized to carbon dioxide (CO_2) and water (H_2O), these hydrocarbons are released as emissions in their original or partially oxidized forms. Unburnt hydrocarbons are significant contributors to air pollution and have various environmental and health impacts.

Carbon monoxide (CO) is a colourless, odourless, and tasteless gas that is highly toxic to humans and animals. It is produced by the incomplete combustion of carbon-containing fuels.

NOx refers to a group of nitrogen oxide gases that are significant pollutants produced primarily through combustion processes.

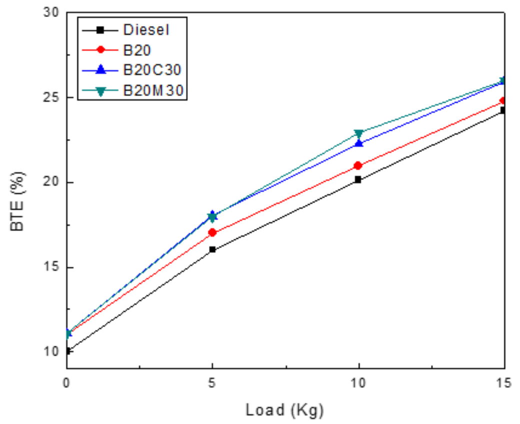

Fig. 5: Load vs BTE

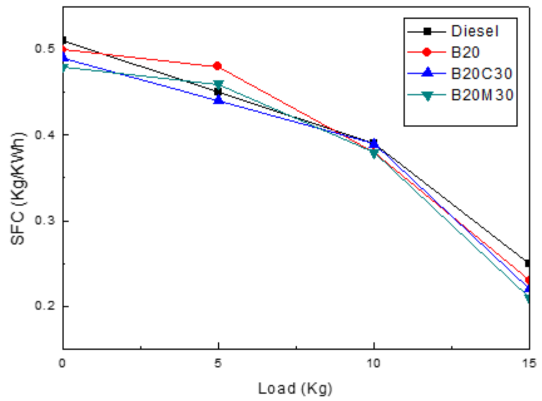

Fig. 6: Load vs SFC

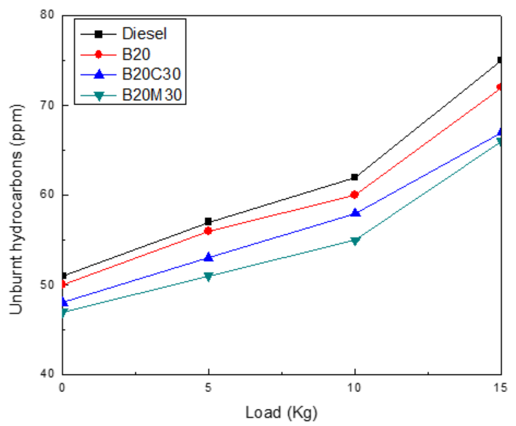

Fig. 7: Load vs UHC

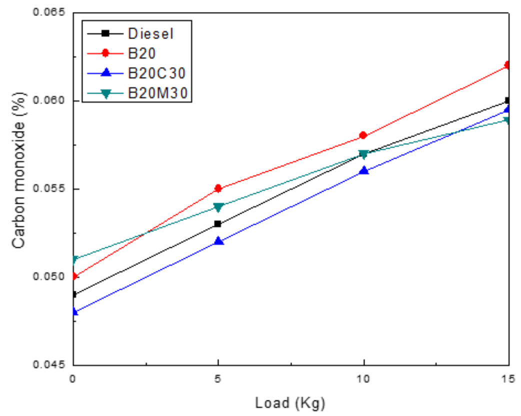

Fig. 8: Load vs CO

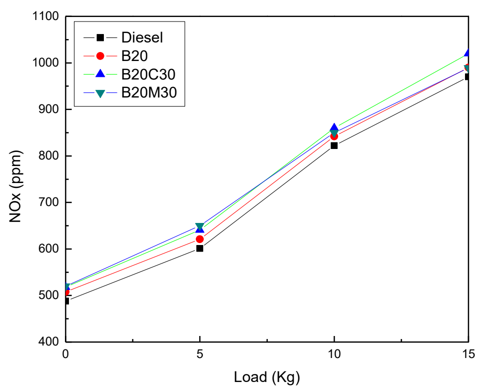

Fig. 9: Load vs NOx

Conclusions

In this project, the comparative analysis of the performance and emissions of CI engine running with diesel, WCO biodiesel (B20) mixed with Calcium Oxide and Magnesium Oxide nanomaterials of 30 ppm dosage has been done, the following conclusions are drawn from the present experimentation is as given below:

- The BTE is improved by adding nanomaterials, which increase from 24.2% to 25.95% and 26.02% for Calcium Oxide (B20C30) and Magnesium Oxide (B20M30) respectively. The SFC decreased by increasing the addition of nanomaterials which decreased from 0.25 Kg/kWh to 0.22 Kg/kWh, 0.21 Kg/KWh, Calcium Oxide (B20C30) and Magnesium nitrate (B20M30) respectively. (figure 5 & 6)
- The reduction in CO and unburnt Hydrocarbons is observed for increasing the nanomaterials. It reduces from 0.06% to 0.0595% and 0.0589% for Calcium Oxide (B20C30) and Magnesium Oxide (B20M30), respectively. The Unburnt Hydrocarbon reduces from 75 ppm to 67 ppm and 66 ppm for Calcium Oxide (B20C30) and Magnesium Oxide (B20M30) respectively. (figure 7 & 8)
- The Nitrous Oxides (NO_x) for Diesel, Calcium oxide (B20C30) and Magnesium oxide (B20M30) are 970 ppm, 1020 ppm and 989 ppm respectively. (figure 9)

In a nutshell, it is noticed from the experimental test results that the improvement in performance emission characteristics of the CI engine is due to the addition of Cerium Oxide and Magnesium Oxide nanomaterials of 30 ppm dosages of 20% WCO nanoparticles compared to diesel. It can be concluded that the addition of nanomaterials improves the performance and emissions of CI engines.

Scope for Future Work

- Carrying out experimental investigations on Diesel engine trucks and buses with WCO Biodiesel to assess its impact on emissions and performance compared to traditional diesel.
- Biodiesel integration into the Circular Economy Model involves developing a network of infrastructure for the collection of WCO and the distribution of biodiesel.
- Development of a Mobile Application and/or Website to connect the biodiesel producer with the source of WCO and vice versa.
- To develop the engine or to do the design modification in the existing engine capable of running on 100% biodiesel.
- To develop an integrated experimental setup or test rig to perform the analysis process for determining viscosity, flash point, fire point, and calorific value in a single setup.
- To find the applications of Biodiesel in sectors other than mobility & transport.