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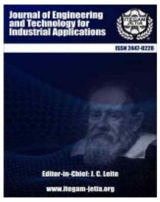

RESEARCH ARTICLE **OPEN ACCESS**

ENVIRONMENTAL EFFECTS OF BIODIESEL ENGINES FUELLED BY WASTE COOKING OIL AND METAL NANO ADDITIVES

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ABSTRACT

The experiment yielded significant findings. Transesterification was used to turn waste cooking oil into biodiesel, a renewable energy source. The fuel mixture ratios were adjusted to measure engine performance and lower fossil fuel emissions. The study examined power generation, torque, consumption per hour, and emissions of unburnt hydrocarbons and carbon dioxide. The diesel engine's power output was 5.2 kilowatts. Biodiesel, derived from discarded leftover cooking oil, was synthesized by blending it with diesel fuel at a concentration of 20%. Engine performance tests revealed no statistically significant variations in power or torque across the various commercial diesel mixes. Notably, the consumption of diesel petroleum for commercial purposes increased by 15% and 20% per hour, respectively. The main advantage was the reduction in carbon dioxide emissions, which was 20% for all combinations of commercial fuel and biodiesel, compared to only commercial diesel.

I. INTRODUCTION

In response to the growing need for oil, biodiesel has emerged as a practical and environmentally friendly substitute for conventional diesel fuel in ICEs, stoves, and other burners. Government policies in several nations have actively encouraged the production and widespread adoption of first-generation biodiesel, increasing usage within these countries. Many countries have encouraged the growth of oil palms for the production of biodiesel, which could potentially meet the energy needs of power plants [1]. It's important to note that first-generation biofuels come with drawbacks. They require a substantial amount of water during production, potentially impacting the food supply and competing with crops meant for human consumption. This sparks a discussion on the efficiency of utilizing food and energy obtained through these resources, which is crucial for developing creative strategies in certain countries. Due to these challenges, there is a growing focus on developing innovative solutions and materials [2]. The development of biodiesel derived from non-food sources and its use has sparked diverse viewpoints about the potential for food and fuel production from these sources. Consequently, it is essential to thoroughly assess this aspect throughout the legislative procedures in different countries.

Researchers from various countries have conducted extensive studies on the effectiveness of internal combustion engines [3]. A thorough online investigation has been conducted on the process of producing biodiesel from non-edible vegetable oils, including comprehensive details on the properties and functionality of the fuel. Numerous plant oils have been investigated by scientists as possible sources of raw materials, including those obtained from cotton, tobacco, flax, jatropha, rubber, and jojoba trees. The cultivation of oil palms for biodiesel production has been advocated in many nations as a means to fulfill the need for this fuel source in electric generators [4]. First-generation biofuels include many drawbacks, such as the potential for competing with food crops and their significant water use during manufacturing. Research has indicated that waste cooking oil has the potential to be transformed into biodiesel that meets global environmental standards and guidelines [5]. According to the study authors, a 98.1% transesterification conversion rate may be attained in producing this biofuel under ideal conditions. Recently, numerous scientists have been devoting considerable time and resources to exploring the viability of biodiesel as a fuel for internal combustion engines. Recent research has examined the efficiency of internal combustion engines concerning transportation [6].

II. MATERIALS AND METHOD

II.1 PRODUCTION OF BIODIESEL

According to the Food and Agriculture Organization (FAO), the first stage is extracting waste cooking oil by heating, which yields around 10 litres. This oil sample is specifically used to conduct acidity analysis. Understanding the acid number of a triglyceride provides valuable insight into the presence of free fatty acids, allowing for an assessment of its acidity level. Potassium hydroxide is essential for titration, while acidity is determined using the acid number index. The oil's acid number will be determined by the investigation. A suitable operating condition free from problems is indicated by a computed result below or equivalent to 5. Nevertheless, it is not recommended to have an acidity index higher than 5 for manufacturing biodiesel because of the increased acid number. However, it is not ideal for biodiesel synthesis and is more beneficially utilized in other fields. To determine the acidity, we mixed a 5-gram sample with 50 millilitres of neutralized ethyl alcohol, heated to temperatures about 50 degrees Celsius. Afterward, an Erlenmeyer flask added a small amount of phenolphthalein to the amalgamation. Afterward, a solution of potassium hydroxide with a concentration of 0.1N was utilized to carry out the titration of the solution [7]. Figure 1 depicts the transesterification process.

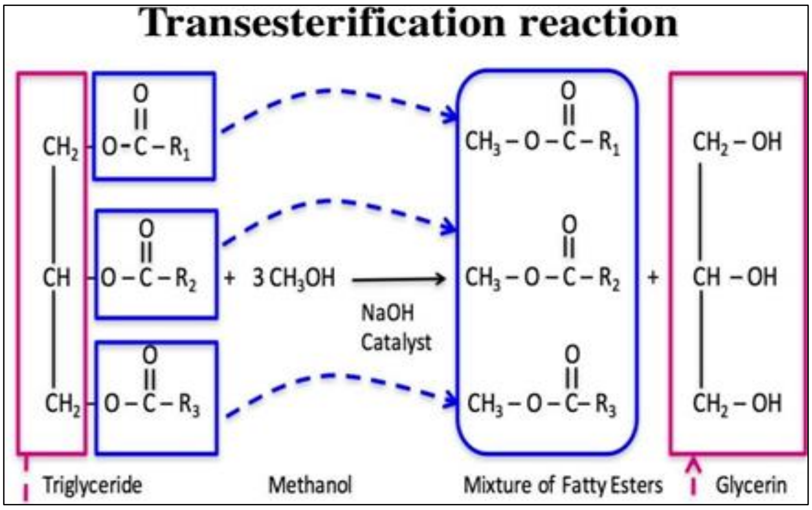

Figure 1: Transesterification process.
Source: Authors, (2024).

Through transesterification, plant and animal oils can be transformed into monoalkyl esters composed of long-chain fatty acids, which can be utilized multiple times. This method can also be applied to animal fats. Additionally, these oils are incorporated into the biodiesel production process. For the experiment, a container designated for this purpose was filled with 10 liters of waste cooking oil. After that, 20% (v/v) methanol was added to the bottle. The quantity of methanol utilized was roughly equivalent to the quantity of oil under examination. The total amount was increased by an equivalent value to the acid number to determine the required number of catalysts. A clear reaction occurred when 8 grams of potassium hydroxide (KOH) were added in equal amounts. Catalyst and methanol (methoxide) were combined before their addition to the sample for reaction. The mixture was agitated for approximately two hours at a temperature ranging from fifty to sixty degrees Celsius. The glycerin was separated through the process of decantation. After that, three to four washes with water were done. This was done because the amount of biodiesel made varied. After this step [8], the steps of drying and filtering were done.

II.2. FUEL SAMPLES

Using a magnetic stirrer, the mixture of 20 percent biodiesel and 80 percent diesel was thoroughly blended to create the waste cooking oil methyl ester blend (B20) for further evaluation. The process described above led to the creation of the final result. Zinc Oxide (ZnO) nanoparticles were evenly distributed in B20 fuel test samples using an ultrasonicator following the established procedure. Dosage levels of 50 and 100 ppm were used. Three different combinations of B20, B20 plus 50 ppm ZnO, and B20 plus 100 ppm ZnO were the starting materials employed in this experiment. Analyze the quality of all the fuels using the ASTM D 6751 test procedure, a widely accepted standard method for evaluating fuel properties. [9]

Table 1: Fuel blends Properties.

S. No	**Properties**	**Diesel**	**Waste Cooking Oil (B20)**	**B20+ 50 ppm CuO**	**B20+100 ppm CuO**
1	Kinetic viscosity cSt	3.05	4.78	4.76	4.73

S. No	Properties	Diesel	Waste Cooking Oil (B20)	B20+ 50 ppm CuO	B20+100 ppm CuO
2	Density kg/m^3	830	889	891	893
3	Calorific value MJ/kg	44.5	39.2	37.4	37.8
4	Flashpoint ^{o}C	60	190	193	195
5	Cetane Number	40	43	46	49

Source: Authors, (2024).

III. EXPERIMENTAL SET-UP

An engine with one cylinder, four strokes, compression ignition, and either a water-cooled or water-injected cooling system was used throughout the testing. To provide more details, the engine utilized in the trials was a Kirloskar, TV1-type engine. The engine in question was utilized to conduct experimental research. This engine can produce a remarkable power output of 5.2 kilowatts, even operating at maximum capacity while maintaining a consistent engine speed of 1500 rpm. This is the maximum power it can generate. Following the manufacturer's specifications, the fuel injection pressure was kept at 210 bar and the timing at 23 degrees before the top dead center (TDC). A constant 80 degrees Celsius coolant temperature was maintained throughout the operation. A system allowed continual coolant recirculation via the cylinder's water jackets. Our piezoelectric transducer was smoothly mounted on the vehicle's cylinder head to measure engine cylinder pressure correctly. Eddy current dynamometers were optionally installed to monitor engine torque. The experimental setup is depicted more compactly in Figure 2, showcasing an illustration of the schematic design.

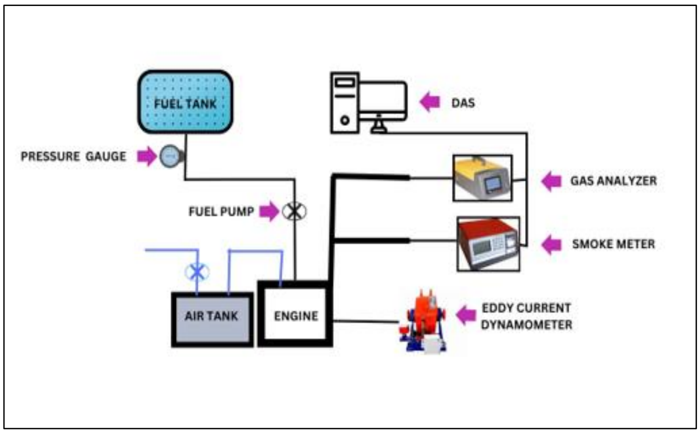

Figure 2: Experimental set-up.
Source: Authors, (2024).

IV. RESULTS AND DISCUSSIONS

IV.1. POWER TEST

The engine's power output is shown in Figure 3 for each kind of fuel combination at 3600 rpm constant speed at four different loads, each of which was increased by 25%. As a point of reference for comparison, the amount of power produced by the B20 fuel mix, which also included 100 parts per million of ZnO, is utilized. There is no statistically significant difference between the power levels for each kind of mixing and the base power, with a mean difference of 0.01 kW. Figure 3 shows the results for each of the various loads placed on the engine and the various mixtures. The foundation's strength (B20) does not shift in any way since it is unaffected by external factors. Similarly, one may see that the power shows a proportionate increase in coordination with the load, which exemplifies a recognizable connection often experienced [10].

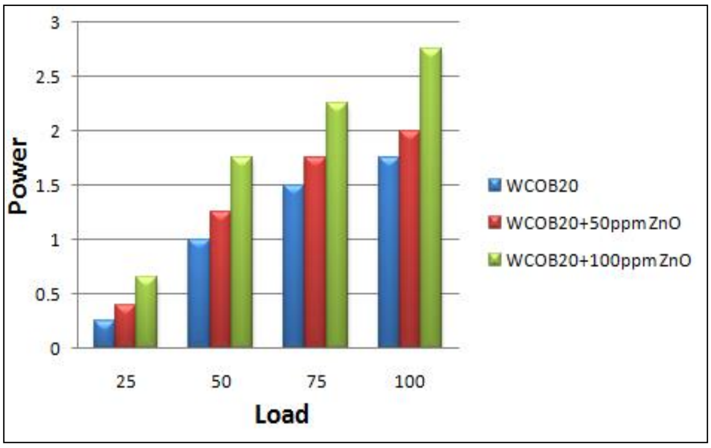

Figure 3: Power varying with an increase in load.
Source: Authors, (2024).

IV.2. TORQUE TEST

Figure 4 demonstrates that the values of the engine's torque are mostly the same regardless of the load group or the kind of mixture. displaying an almost linear upward tendency in conjunction with a rising trend as the load rises. The data in the picture demonstrate that the variety of gasoline used does not impact the engine's torque output [11]. This corresponds to each load applied to the engine, and the propensity for this to occur increases as the load-imposed increases (B20+100ppm ZnO), as the trend line demonstrates.

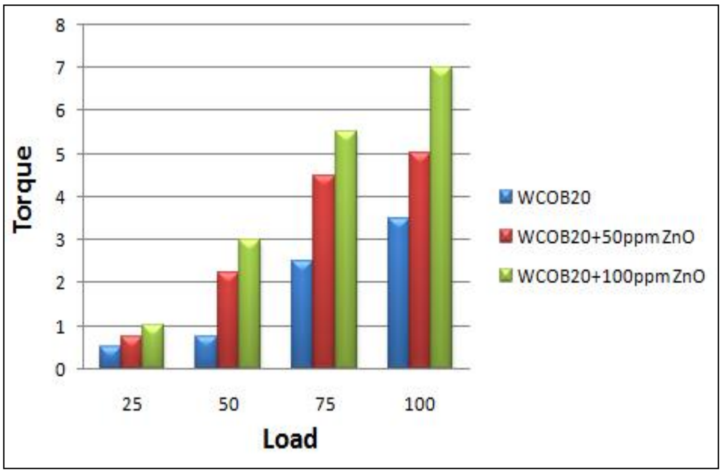

Figure 4: Torque varying with an increase in load
Source: Authors, (2024).

IV.3. CONSUMPTION TEST

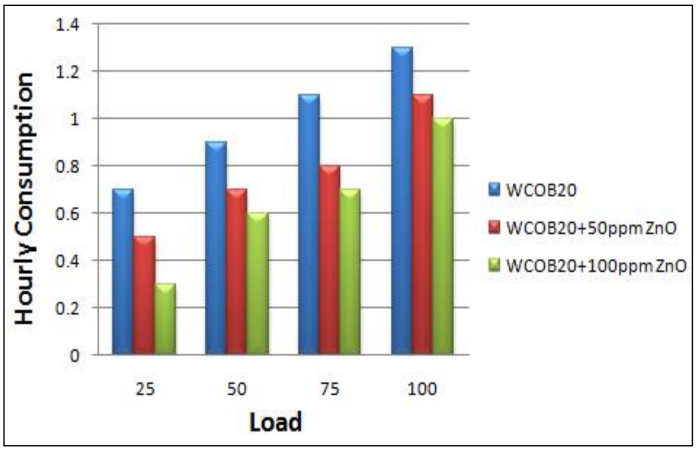

Figure 5: Hourly consumption varies with an increase in the load.
Source: Authors, (2024).

The findings shown in Figure 5 indicate that the hourly consumption of commercial gasoline is consistently less than that seen with the blends throughout various load conditions [12]. Because biodiesel has a lower calorific value than B20, some have speculated that the increased usage of a combination of commercial gasoline and waste cooking oil biodiesel represents some compensation. The dependence of the hourly consumption curve on the combinations used, which depends on the loads adjusting to the anticipated characteristic, is shown in Figure 5 [13]. The biodiesel combination provides the least hourly usage. The use of all fuel types shows a decrease.

IV.4. UHC EMISSION TEST

Figure 6 undeniably demonstrates the escalation in unburned hydrocarbons (UHC) emissions in both low-load and high-load conditions, culminating in maximum power [13]. According to the established theoretical framework, a restricted oxygen supply undeniably results in higher unburned hydrocarbon (UHC) emissions. The research unequivocally indicates that the fuel exhibits a higher richness than the fuel-air mixture ratio [14]. Figure 6 unequivocally portrays a consistent reduction in UHC emissions for all mixtures throughout the operational range. Furthermore, it is indisputable that the B20+100ppm ZnO combination exhibits even lower emissions than the B20 mixture [15].

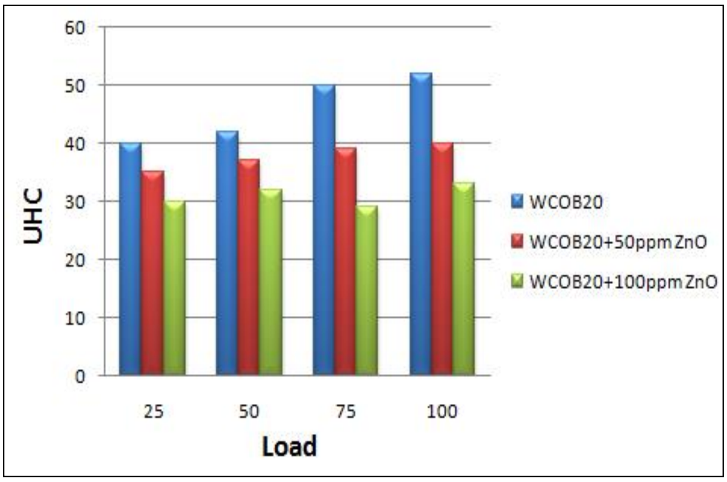

Figure 6: UHC varies with an increase in load.
Source: Authors, (2024).

IV.5. CO_2 EMISSION TEST

Based on the information provided in Figure 7, there appears to be a clear positive correlation between carbon dioxide (CO2) emissions and the increase in all loads. It's worth noting that incorporating leftover cooking oil biodiesel into the fuel mixture can lead to a substantial reduction of approximately 20% to 25% in total CO2 emissions [16]. The data depicted in Figure 7 demonstrates the CO2 emissions for different engine loads when using B20 fuel. Notably, the concentration of carbon dioxide (CO2) is highest in the general atmosphere, including the B20 blend combination [17]. Utilizing a B20 gasoline mix with 100 ppm of Zinc Oxide (ZnO) has the potential to diminish greenhouse gas emissions significantly.

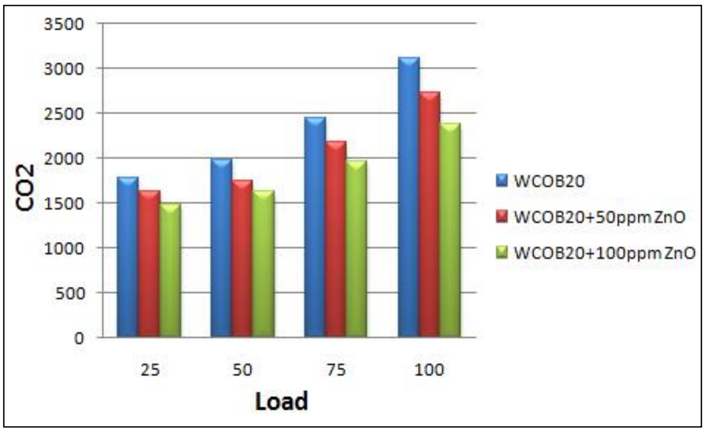

Figure 7: CO_2 varying with an increase in load.
Source: Authors, (2024).

V. CONCLUSION

Waste cooking oil is an important biodiesel feedstock. Residual cooking oil biodiesel is a third- or fourth-generation renewable fuel with little food security effect. Waste cooking oil biodiesel minimizes greenhouse gases. Energy-wise, waste cooking oil biodiesel beats diesel. ZnO nanoparticle-blended biodiesel outperforms B20 in power and emissions. The power of the base (B20) remains constant and does not undergo any changes. Similarly, it can be noticed that the power exhibits a proportional rise in tandem with the load, so illustrating a discernible relationship that is often encountered. To each load that is applied on the engine, and the propensity of this to occur increases as the load that is imposed torque increases (B20+100ppm ZnO), as the trend line demonstrates. The biodiesel combination provides the least hourly usage. The use of all fuel types shows a decrease. The UHC emission is consistently reduced for all mixtures. Furthermore, it is seen that the combination including B20+100ppm ZnO exhibits even lower emissions compared to the B20 mixture. It is seen that the aforementioned data demonstrates a significant decrease of around 20% to 25% in overall CO2 emissions.

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