International Journal of Materials, Mechanics, Mechatronics and Manufacturing
ISSN: 2583-5688 Volume: 003 (2024), pp. 01-10

The impact of carbon nanotube additions on diesel engine performance and exhaust emissions using WCO-biodiesel and diesel blends: an experimental approach

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Abstract

The limited supply of conventional power sources, such as diesel and gasoline, is depleting them daily. However, it's difficult to find alternative fuels. It is therefore essential to find a variety of CNTs with low emission potential from transportation engines in order to satisfy the world's growing energy needs and reduce emissions into the environment. Here, we investigated the performance and exhaust emissions of diesel engines using B0, B10, B20, and B30 blends, which contain carbon nanotubes at 25ppm and 50ppm. The brake-specific fuel consumption (BSFC), brake thermal efficiency (BTE), and CO and HC emissions of the fuel blends are described in this work. The current study used loads ranging from 8 kg to 12 kg while running at a constant 1500 rpm with a set compression ratio of 18CR. The study's conclusions will be useful to future researchers when creating cars and other vehicles that use CNT blends in addition to renewable fuels.

Keywords: Biodiesel, Brake Thermal Efficiency, Brake Specific Fuel Consumption, Exhaust Emissions, Nanoparticles

Introduction

In order to slow down climate change, present policies mainly aim to reduce emissions of carbon dioxide and other dangerous pollutants. Human activity, particularly the burning of conventional fuels, which have a high carbon content and generate substantial hydrocarbon emissions, is the main cause of greenhouse gas emissions from automobiles. Consequently, the development of sustainable fossil fuel substitutes is becoming increasingly significant. Compared to conventional feedstock's, algae can produce more biodiesel per unit of growth area because of their high lipid content (up to 70 %). The improved environmental sustainability of algae is a result of their roughly ten-fold higher capacity to absorb carbon dioxide than land-based plants.
Energy is incredibly precious and vital to humankind, and it may be created in many different ways. Natural resources including coal, wood, and water were consumed more often in the preceding century as economic growth raised the demand for energy. Climate change is impacted by the rising need for energy, though. Consequently, it has brought attention to the necessity of developing alternative energy sources, such as biofuels.

Currently, biofuels account for 9.1% of the total. The organic materials (also known as biomass) produced by plants and other living organisms that can be continuously cultivated and harvested make up biofuels, a type of energy fuel. Biodiesel (derived from vegetable oils, recycled wax, or animal fats), bioethanol (alcohol produced by fermenting crops with sugar and starch, especially corn), and biogas are the three most popular forms of biofuels. Transesterification can be done both homogeneously and heterogeneously using acid and base catalysts. Because they provide a faster rate than acidic catalysts, alkali catalysts based on sodium or potassium hydroxide are more common in transesterification processes.

Globally, biodiesel is becoming more and more popular due to its fuel properties and compatibility. The right feedstock selection is essential to the production of biodiesel. Since the feedstock accounts for 70% of the product's cost, the feedstock selection has a big influence on the manufacturing of biodiesel.

The manufacture of biodiesel from waste and non-food plant oils lessens reliance on food crops, which may result in higher food costs. Because WCO and neem oil are typically cheap, biodiesel made from them is a more affordable option than petroleum diesel. By improving combustion characteristics and lowering wear on engine components, using carbon nanotubes (CNTs) with biodiesel can increase fuel economy and prolong engine life. This lowers fuel usage and maintenance expenses, which has long-term economic benefits. It has been demonstrated that adding nano additives, such as carbon nanotubes, to biodiesel blends can increase fuel performance, lower emissions, and improve combustion efficiency. By acting as catalysts for combustion and enhancing the fuel's thermal conductivity, CNTs promote more thorough combustion. To fully comprehend their effects and maximize their utilization in biodiesel, more research is necessary.

Although the results of earlier research on biodiesel have been encouraging, issues with fuel stability, emissions, and performance still exist. This study intends to overcome these constraints and optimize an alternative fuel that can perform on par with or even better than traditional diesel by combining WCO and neem oil biodiesel with CNTs. The literature review demonstrates that the performance, emission characteristics, and blend of biodiesel in the CI engine were examined. There is a study gap, though, in examining the performance and emission characteristics of a CI engine using different types of biodiesel made from different types of waste. There is little research on biodiesel made from WCO and neem oil, whereas most studies on biodiesel concentrate on common feedstocks like soybean, canola, or palm oil. These widely accessible, inexpensive, and non-edible feedstocks have special chemical qualities that need more research in order to fully understand their emissions, combustion characteristics, and suitability for diesel engines. Few studies have thoroughly examined the financial and environmental benefits of employing waste and non-food oils in large-scale biodiesel production, despite the fact that WCO and neem oil show promise for sustainable biodiesel production. Rather than pure biodiesel or completely alternative fuel blends, the majority of research concentrates on biodiesel-diesel mixes (such as B20 or B50). Investigating biodiesel as a full substitute for diesel, particularly with mixes of WCO and neem oil that don't contain diesel, is still in its infancy. The development of a completely alternative fuel that does away with reliance on fossil fuels is the goal of this project. The performance of engines and the modifications required when utilizing high percentages or 100% biodiesel blends in conventional diesel engines, particularly under changing load and speed situations, have not been thoroughly studied.

2. Materials and Methods

2.1 *Preparation of WCO Biodiesel:*

In order to eliminate the solid precipitation and food residue that were present in WCO, the oil was first filtered. Following that, the oil was placed in a beaker and heated to eliminate any remaining moisture. To eliminate the water content in the oil, around 200 milliliters were heated to 120 degrees Celsius. KOH (potassium hydroxide) was used as a catalyst for the transesterification of WCO, and methanol was combined with the catalyst. Then, using a magnetic stirrer, oils were combined with methanol and KOH for an hour at a temperature of about 60 to 70 °C. After combining, the mixture was allowed to settle for 24 hours. The WCO ester was extracted independently from the top layer after the fixed glycerol layer was safely removed from the bottom. Methanol was extracted from the biodiesel by washing waste cooking oil methyl ester (WCOME) three or four times in warm water. The WCOME was heated to 150 degrees Celsius for 15 to 20 minutes in order to eliminate any remaining water. Then, methanol and water were removed to produce pure biodiesel, which is suitable fuel for diesel engines.

Fig. 1. Transesterification Process for Biodiesel Production

2.2 Multi-Walled Carbon Nanotubes (MWCNTs)

MWCNTs are often explained using two models: the Russian doll and the parchment model. Graphite sheets are arranged into concentric cylinders in the Russian doll model to mimic the nested configuration of Russian dolls. On the other hand, the parchment model compares the structure to a single sheet of graphite that has been rolled over itself, much like a newspaper or a parchment scroll. The interlayer spacing in multiwalled nanotubes is approximately 0.33 nm, comparable to the spacing between graphene layers in graphite. Despite their intricate complexity and structural diversity, MWCNTs are simpler to produce than single-walled carbon nanotubes (SWCNTs) across various processing conditions. Scanning Transmission Electron Microscopy (TEM) analysis is commonly utilized to examine the structure of MWCNTs. Because they are reasonably easy to produce in large quantities at a reasonable cost, WCNTs have wide-ranging uses. Since they are more abundant than SWCNTs, they are more practical for a wide range of uses. Internal combustion engines can use carbon nanotubes to reduce fuel consumption and friction losses. When the suspended nanoparticles' concentration or size is constant, the nanotubes' stability is preserved. Comparing the sonication method to magnetic stirring, the former offers superior dispersion and a reduced chance of particle agglomeration. By applying ultrasonic waves to the nanofluid, sonication helps to produce a more uniform suspension.

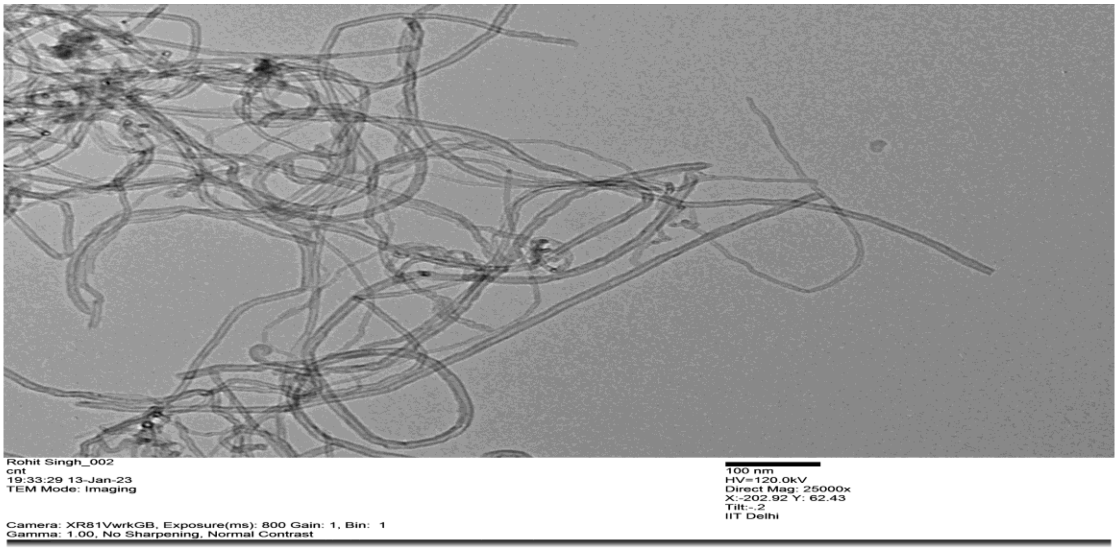

Fig.2. TEM Test (IIT Delhi)

Table 1.Properties of MWCNTs.

S.NO	PARAMETERS	CNT Particles
1	The mean particle dimension	66nm
2	Formula Weight	80.39g/mol
3	Specific Surface Area	$15m^2/g$
4	Appearance	Black
5	Structure	Powder
6	MF	80.39g/mol
7	MP	2350℃
8	BP	3450℃
9	Solubility in water	Insoluble

2.3. Experimentation

An exhaust gas analyzer was used to monitor NOx emissions, an AVL smoke meter was used to measure smoke density, and an eddy current dynamometer was used to quantify the load. An AVL five-gas analyzer was used to measure additional contaminants. An AVL combustion analyzer was used to assess the engine's combustion characteristics. Over a predetermined amount of time, fuel consumption was precisely tracked using an aburette, and the engine's fuel consumption was measured using a timer. A blend of 20% waste cooking oil (WCO), 30 ppm Multi-Walled Carbon Nanotubes (MWCT), and ethanol concentrations ranging from 5 to 10% was used in the experiments. This configuration made it easier to evaluate the engine's characteristics under various operating situations and fuel compositions.

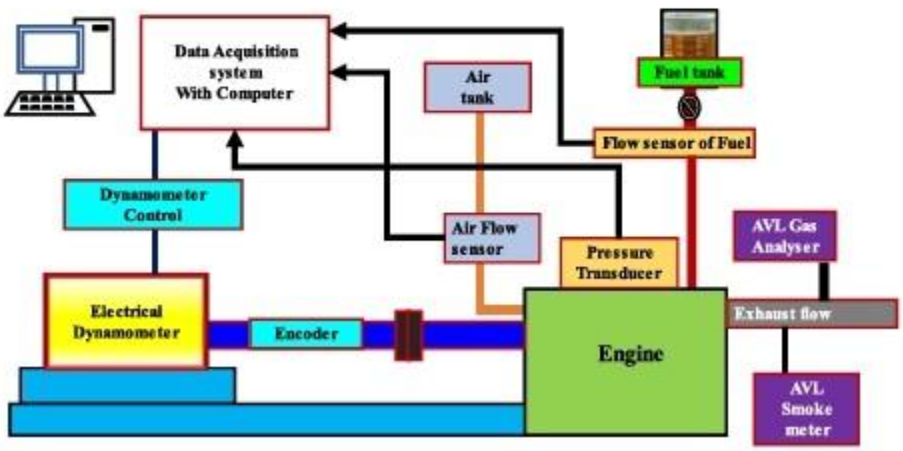

Fig.3. Schematic Representation of Experimental Setup.

Because the purpose of the study is to assess the effectiveness of the biodiesel blends and the effects of nanoparticles, testing at a single speed reduces the complexity of the experiment. The study offers comprehensive insights into fuel performance across common engine demands without adding further speed-dependent variables because it concentrates on load fluctuations rather than speed.

The engine is run at the suggested speed of 1500 rpm for every test. For every test, the engine is started using diesel fuel and given 30 minutes to stabilize. The viscosity in centistokes (cSt) was calculated by measuring the flow time via the capillary tube while the fuel was kept at 40°C. After inserting the fuel into the capillary tube, the flow time was recorded. The viscometer calibration constant was used to convert this time to viscosity in centistokes (cSt). Using a graduated cylinder and a glass hydrometer, the density at 15°C was examined in accordance with ASTMD1298. By setting the sample in a graduated cylinder at 15°C, taking a reading on the hydrometer, and computing the density in kilograms per cubic meter, the density was determined using a hydrometer.

3. Results and Discussion

In this study, trials were conducted in an engine with various fuel mixtures at varied loading levels, and each reading was taken in a steady-state environment. When nanoparticles are added to a diesel engine, the extracted fuel samples' performance, combustion, and emission properties are investigated, and the results are contrasted with those of regular diesel fuel.

3.1. Performance Test:

(A) BTE:

This could offer clear evidence that mechanical power can be produced from thermal energy. If the brakes are strong or durable enough, that might be possible.

(fluid-mass*CV)/BP = BTE.

Table 2.BTE of Different Formulations

CR 18	0 PPM			25 PPM			50 PPM		
	8 KG	**10 KG**	**12 KG**	**8 KG**	**10 KG**	**12KG**	**8 KG**	**10 KG**	**12KG**
B0	27.68	28.32	29.2	28.26	28.974	29.912	28.475	29.15	30.105
B10	24.73	26.43	27.06	25.56	27.16	27.84	25.80	27.39	28.13
B20	24.97	25.98	26.88	25.00	26.72	27.08	25.14	26.88	27.00
B30	23.82	24.87	25.74	24.57	25.92	26.43	24.90	25.14	26.15

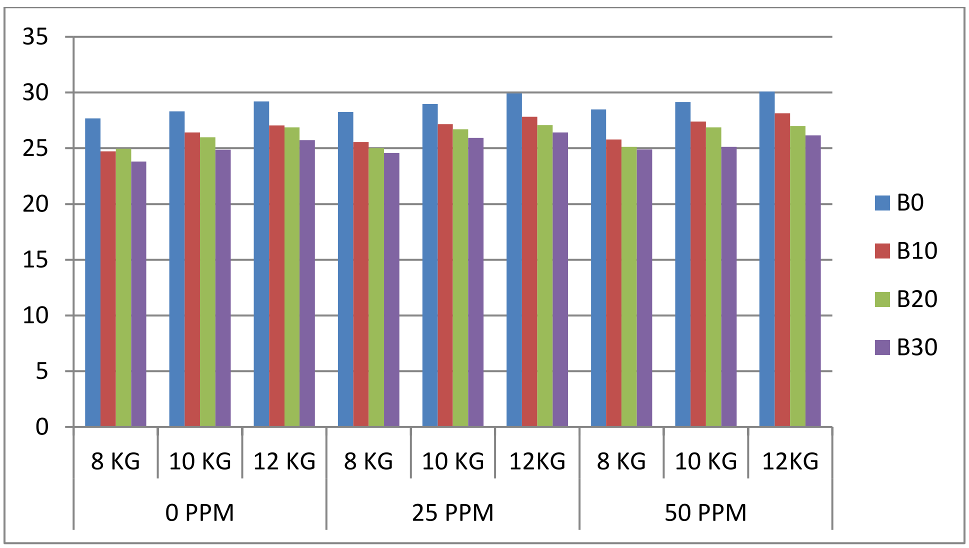

Fig.4. BTE vs Load

When compared to conventional fuels, the B10 fuel blend, including 50 ppm CNT nanoparticles, exhibits a higher BTE value. This is because CNT nanoparticles, which act as a catalyst to stimulate the chemical process and encourage better combustion and higher BTE, were introduced to the B10C50 mix, which had a higher oxygen concentration than diesel.

(B).BSFC:

An engine needs BSFC worth of fuel to create one unit of energy. Fuel required to generate a driving unit is known as engine-specific energy consumption.

BSFC = BP/ (FC*CV)

Table 3. BSFC of Different Formulations

CR 18	0 PPM			25 PPM			50 PPM		
	8 KG	**10 KG**	**12 KG**	**8 KG**	**10 KG**	**12KG**	**8 KG**	**10 KG**	**12KG**
B0	.210	.206	.202	.200	.197	.192	.194	.191	.186
B10	.242	.238	.235	.238	.233	.230	.236	.232	.228
B20	.275	.257	.249	.270	.252	.344	.269	.250	.241
B30	.286	.277	.265	.280	.271	.259	.278	.269	.257

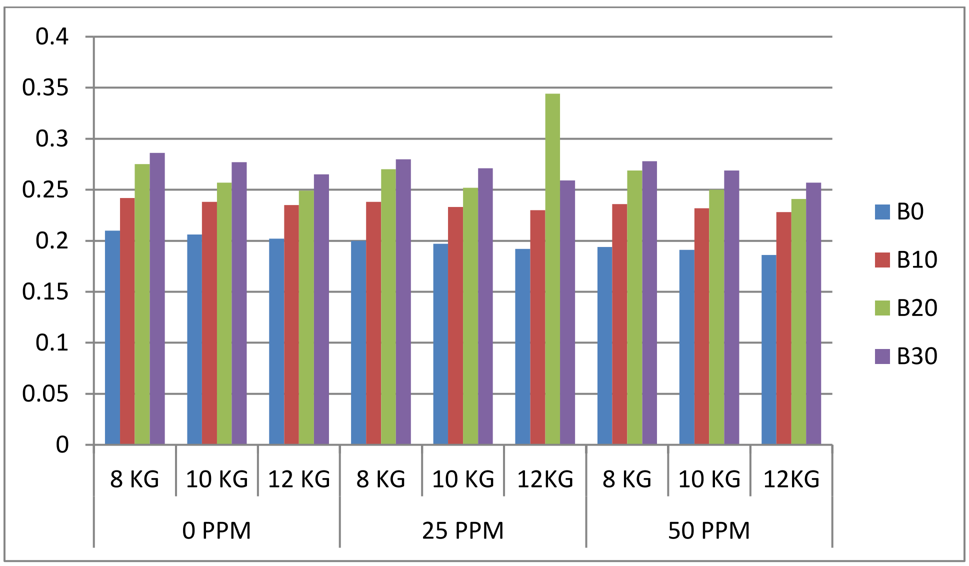

Fig.5. BSFC vs Load

The density of the fuel increases when CNT nanoparticles are added to diesel biodiesel blends, increasing the volume of fuel extracted and the pull on the injection pump. But as more fuel is pulled, the oxygen molecules in the biodiesel burn more completely, generating more power from the same amount of fuel. B10 with CNT 50 ppm demonstrated lower SFC than B10 with CNT 0 ppm because of better performance with higher power output for the amount of fuel used.

3.2. Emission Test

(A) UBHC Emission:

A poorer oxidation reaction and inadequate oxygen content during combustion cause the engine to emit UHC. Additionally, a key element in the production of UHC in diesel engines is the fuel-air mix in the combustion chamber. Higher UHC emissions are also caused by low-temperature combustion and decreased oxygen content available.

Table 4. UBHC of Different Formulations

CR 18	0 PPM			25 PPM			50 PPM		
	8 KG	10 KG	12 KG	8 KG	10 KG	12KG	8 KG	10 KG	12KG
B0	35.5	34.9	33.2	33.7	31.71	28.57	30.83	28.67	26.45
B10	32.806	31.068	29.024	31.99	30.13	28.24	30.24	29.41	27.15
B20	29.333	28.0303	26.840	28.78	27.42	25.135	27.58	26.23	24.42
B30	27.159	26.142	25.288	26.52	25.432	24.78	25.33	24.14	23.52

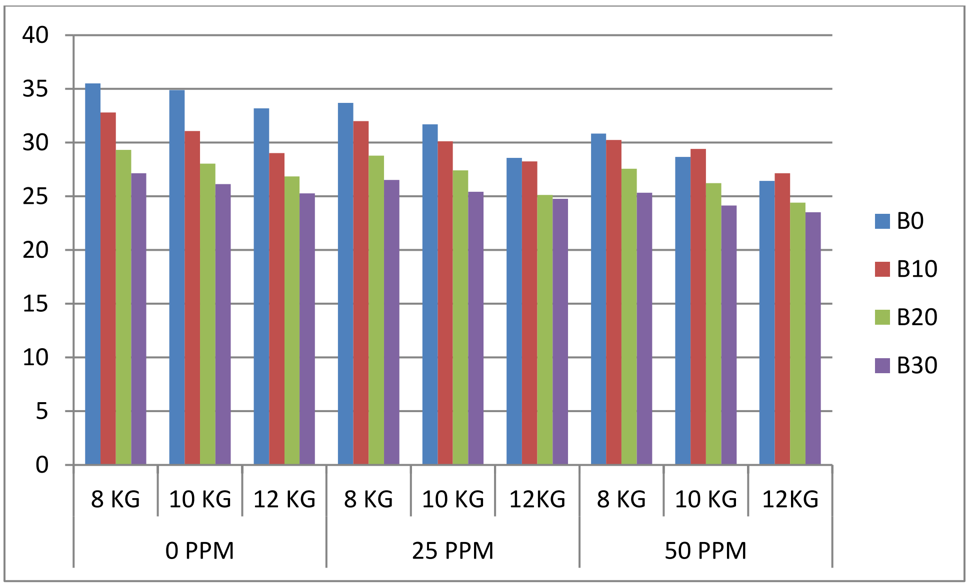

Fig.6. UBHC vs Load

Lower UHC emission was seen in the B30, CNT 50 ppm blend. CNT nanoparticles in WCO biodiesel may be functioning as a catalyst in this instance because of their high surface area per volume and subsequent secondary atomization. Improved hydrocarbon oxidation and decreased UHC emissions were achieved using B30 and CNT 50ppm mix fuel.

4. Conclusion

The feasibility of producing biodiesel from Waste Cooking Oil (WCO) oil through transesterification for use in single-cylinder diesel engines is examined in this experimental investigation. Incorporating Carbon Nanotube (CNT) nanoparticles into biodiesel formulations is intended to improve environmental sustainability, decrease emissions, improve combustion efficiency, and cut operating costs. Under varied engine loads, the study examined a variety of fuel blends, including blends of biodiesel and pure diesel (D), and the following findings were obtained:

1. The greatest BTE is 30.105% when comparing blend B-0 with CNT nano particles-25ppm and 50ppm to diesel at a 12-kilogram load.

2. The mix of B-0 with C-25 ppm and 50ppm has a lower BSFC of .186 kg when compared to plain diesel with a 12 kilogram load.
3. The lowest HC emission is 23.52mg/nm^3 when comparing B30 with C50ppm to B-0 at 12 kg load.

Acknowledgments
The BIET Jhansi provided the lab for this study, for which the authors are grateful. We also thank SRMU Barabanki (India) and IIT Delhi (India) for providing the tools, space, and equipment needed to complete this research work.

Nomenclature

MWCNT: Multi Walled Carbon Nano Tubes

CV: Calorific Value

BTE : Brake Thermal Efficiency

KV : Kinematic Viscosity

BSFC: Brake Specific Fuel Consumption

CR: Compression Ratio

PPM: Parts Per Million

HC: Hydro Carbon

BP: Brake Power

FC: Fuel Consumption

TEM: Transmission Electron Microscopy

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