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Effects of CNT Nanoparticles' on the Performance and Emission Study of CI Engines Utilizing a Combination of Diesel and Waste Cooking Oil Biodiesel

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Abstract

In this work, the effects of adding Multi-Walled Carbon Nanotubes (MWCNT) along with leftover cooking oil on a diesel engine's efficiency, emissions, and combustion properties were studied. After TEM examination, using an ultrasonicator, the MWCNT was combined with biodiesel fuel made from leftover cooking oil at concentrations of 0 and 25, parts per million. A constant speed of 1500 rpm was used to test these blends while varying engine loads. The experimental results indicated that the cylinder peak pressure, peak pressure rise rate, and heat release rate were slightly lower when MWCNTs were added to WCO fuel compared to pure WCO fuel. The innovative fuel mix significantly decreased CO and BSFC. Not only that, but the specific fuel consumption was lower than with pure WCO fuel, and the brake thermal efficiency was significantly altered.25 ppm was found to be the proper dose level of MWCNTs with WCO fuel based on engine capability and pollutant comparisons. All engine performance metrics significantly increased as a result.

Keywords: *BSFC, Engine, MWCNT, Nanoparticles, WCO*

1.0 Introduction

The rapidly expanding global population is driving up energy demand. The industrial use of fossil fuels contaminates clean water supplies, and the atmosphere's concentration of greenhouse gases is rapidly increasing. The COVID-19 pandemic, which has lately swept over the world, has caused an end to industrial production[1]. The result was a notable decrease in greenhouse gas concentrations in the atmosphere. Internal combustion engines are another source of greenhouse gases, in addition to industrial activity[2].

Automobile emission values are therefore controlled and limited. Carbon monoxide (CO) and Hydrocarbon (HC) emissions increased fourfold, Nitrogen Oxide (NOx) emissions increased fourfold, and soot emissions increased sixteenfold when compared to the 1996-enacted EURO II limits on emissions for automobiles equipped with Compression Ignition (CI) engines and the current EURO VI emission standards[3].

Future emission restrictions on petroleum fuels used in SI and CI engines are expected to be very difficult to implement. Because of this, hybrid and electric vehicles will replace Spark Ignition (SI) and Combustion Ignition (CI) engines shortly. Public transportation, heavy-duty road vehicles, and marine transportation will all continue to utilize IC engines for some time to come, even if passenger cars stop using them[4]. As a result, researchers have been looking at whether alternative fuels are suitable for diesel engines for a very long time. Here, the main

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goals are to use fuels derived from natural energy sources to reduce reliance on fossil fuels and manage harmful exhaust emissions with cleaner combustion.

Because of their increased fuel efficiency, longer lifespan, and improved reliability, diesel engines are crucial in many areas, including building, farming, power, and industrial[5]. This leads to a high demand for energy and a constant increase in the price of fossil fuels. Toxic emissions from diesel engines may also cause major air quality issues, diminished ozone layer, and other health issues. This leads the researchers to switch out the gasoline for another fuel that works with compression ignition engines.

However, the cost of both products on the market has increased due to the process of converting edible oil into biodiesel[6]. Therefore, non-edible or waste oil should be the source of biomass resources.

1.1 Waste Cooking Biodiesel

Raw waste oil is said to be the most cost-effective feedstock for biodiesel because it is so cheap when in contrast to freshly generated edible or non-edible oils[7]. However, the primary barrier to the direct use of spent cooking oil in different types of combustion systems is its high viscosity, which is significantly higher than that of diesel fuel[8]. According to Attia and Hassaneen, this is because of their huge molecular mass and chemical structure. Because transesterification is thought to be the most efficient strategy to deal with the viscosity issue with raw oil, the majority of scientists recommend utilizing it to handle this particular problem[9]. The majority of scholars and scientists have been trying to investigate the impacts of adding nanoparticles to biodiesel fuels in recent decades because of the extraordinary impact this addition has on the fuel's combustion parameters[10]. The huge surface area to volume ratio and strong thermal insulation of the nanocrystals are the main causes of this effect. Through their catalytic action in the combustion zone, these additives dramatically reduce emissions[7]. By increasing the heat transfer between the fuel and air, these additives have also been shown to quicken combustion and reduce ignition delay[11].

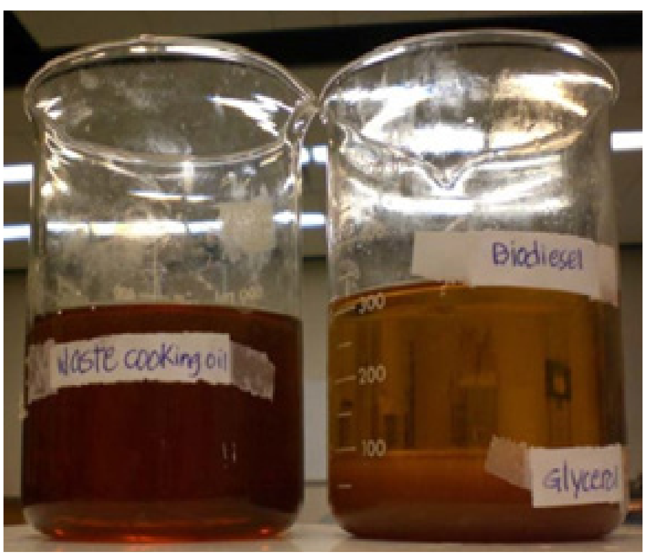

Figure 1. Waste cooking oil and biodiesel.

1.2 Admixtures

An investigation was conducted on the effects of adding CNTs to biodiesel dispersion oil at dosage levels of 25 and 50 ppm and particle sizes of 50 nm[12]. They showed that the cylinder pressure and heat release rate increased by 5% and 4%, respectively, while the fuel consumption associated with brakes was reduced by around 10%. Basha and Anand[13] also looked examined the effects of adding alumina to jatropha biodiesel at dosage levels of 25 and 50 ppm, with a particle size of 51 nm, on the effectiveness of a diesel engine.

In the last few years, a lot of research has been conducted on a variety of metal oxide-based nanoparticle compounds, such as oxides of zinc, oxides of titanium, oxides of aluminium, and cerium oxide, to enhance the combustion of diesel and biodiesel and lower emissions from diesel engines[14]. The environment and public health have been demonstrated to be in danger from metal compounds and additives derived from combustion byproducts, notwithstanding the advantages that have been previously described[15]. For example, the majority of academic specialists have concluded that metal oxide nanoparticles can result in a variety of health for instance, most academic professionals have concluded that metallic oxide nanoparticles can cause a range of health conditions, such as breathing difficulties, lung-related ailments, and skin allergies (Goswami *et al*)[16].

However, several studies have shown that MWCNTs could be an environmentally benign fuel additive for efficiently improving the combustion properties of diesel-biodiesel blended fuels because of their low harmful

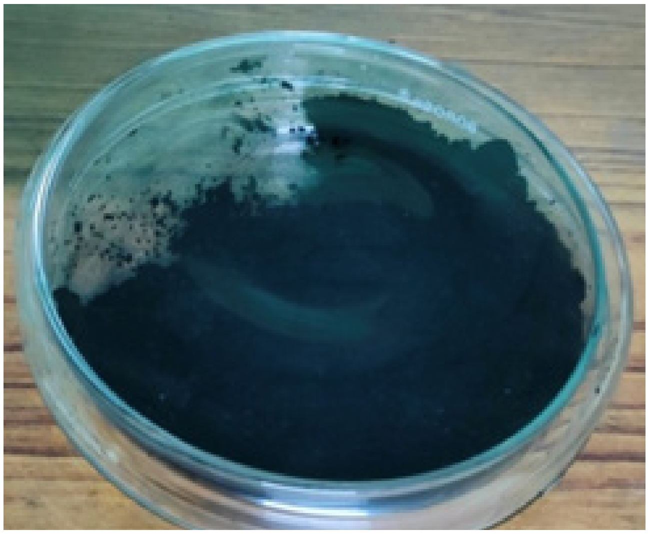

Figure 2. MWCNTs.

effects, elevated density of energy, and high thermal insulation. MWCNTs and related carbon nanostructures are widely used in many different applications, such as heat transmission, chemical sensors, batteries, and transparent conductors, because of their advantageous qualities[17]. Because of their ultra-thin, layered nanostructure, many oxygen functional groups, and high surface area to volume ratio, MWCNTs have chemically energetic locations for full combustion[18].

To improve the engine's combustion and emission characteristics, most recently released research findings have focused on optimizing various metallic nanoparticles as fuel enhancers for diesel and biodiesel[19]. Therefore, the purpose of this work is to examine how the efficiency, burning, and pollutant attributes of a gasoline engine operating on clean WCO fuel are affected when MWCNTs are utilized as catalysts[20].

This study looks at using a blend of biodiesel and waste cooking fuel to power diesel engines. Additionally, the research shows how to improve efficiency and reduce emissions in biodiesel-diesel blends by adding nanofuel additives (Multi-Walled Carbon Nano Tubes)[21].

2.0 MWCNTs and WCO Preparation

Using varying proportions of 25 ppm and 50 ppm, MWCNT nanoparticles were dosed into blends of

Figure 3. Fuel preparation by ultrasonic probe processor.

Table1. Properties of CNT nanomaterials

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

commercially available biodiesel for experimental reasons[22]. A 125W Power, 20KHz Ultrasonicfrequency, Ultrasonic Probe Processor (made by Leela Electronics) with a 5-second ON and 10-second OFF cycle was utilized for 90 minutes for each blend to achieve the proper mixing of nanomaterials in the blends. Subsequently, the mixes' engine effectiveness and emission features were analyzed and juxtaposed with those of diesel[23].

3.0 Testing Setup

An electrodynamic dynamometer was connected to a 4-stroke, 1-cylinder liquid diesel engine in the present study[24]. The system is equipped with the necessary tools to calculate the crank angle and combust intensity. Brake thermal effect, specific heat relevance, isentropic efficiency, volumetric efficiency, FP, specified power, and IMEP are supported by the design[25].

Figure 4. Engine setup for performance test.

4.0 Results and Discussion

WCO biodiesel was utilized in an I-cylinder, 4-stroke, water-cooled VCR engine. It was created in the present work employing a 2-stage transesterification technique with diesel and CNT nanoparticles as additives.

At IIT Delhi, the random dispersion of nanoparticles in mixes was confirmed using TEM on HRTEM, JEOL GEM 2100. The TEM picture of dispersed MWCNT nanoparticles is shown in Figure 5.

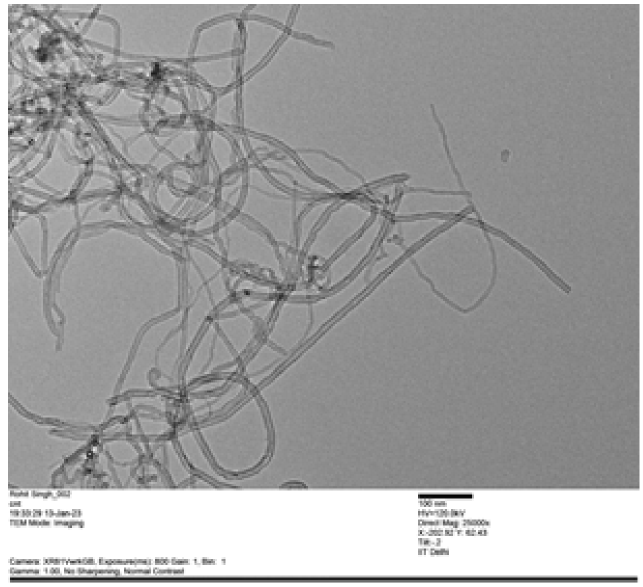

Figure 5. TEM image.

4.1 Properties of Various Concentrations

a. Calorific value: The term "calorie value" refers to the amount of energy that is generated, stored, and released when one kilogram of a specific material is burned.

Table 2. The calorific value of various mixtures

Sr.Number	Name of Sample	CV (kJ/kg)
1	B0	42698
2	B10	41185
3	B20	41253
4	B0C25	41357
5	B10C25	42756
6	B20C25	43002

As the graph above illustrates, diesel has a CV of 42698 kJ/kg, but the value increases progressively when nanoparticles are added.

b. Kinematic Viscosity: Kinematic viscosity is used in this example to calculate the different formulations of diesel and biodiesel. Gravity assesses the natural

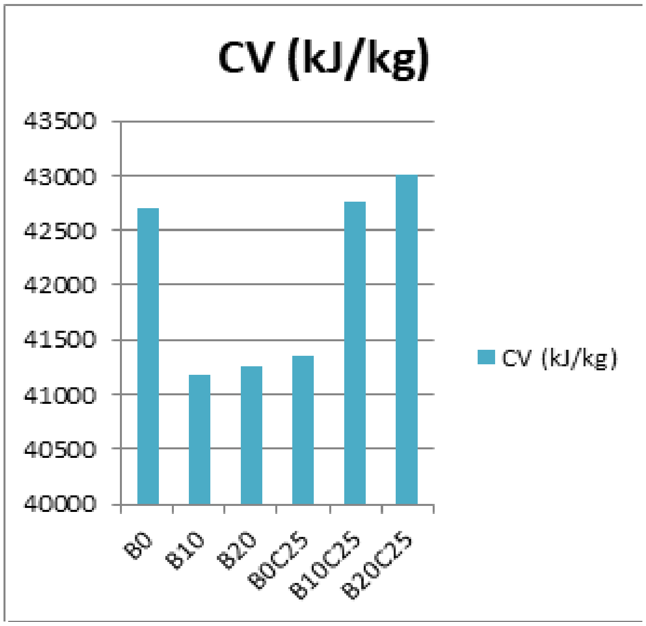

Figure 6. CV of different blends.

Table 3. KV of various mixtures

SerialNo.	Name of Sample	Result (Cst)
1	B0	3
2	B10	2.8
3	B20	2.7
4	B0C25	3.1
5	B10C25	3.2
6	B20C25	3.4

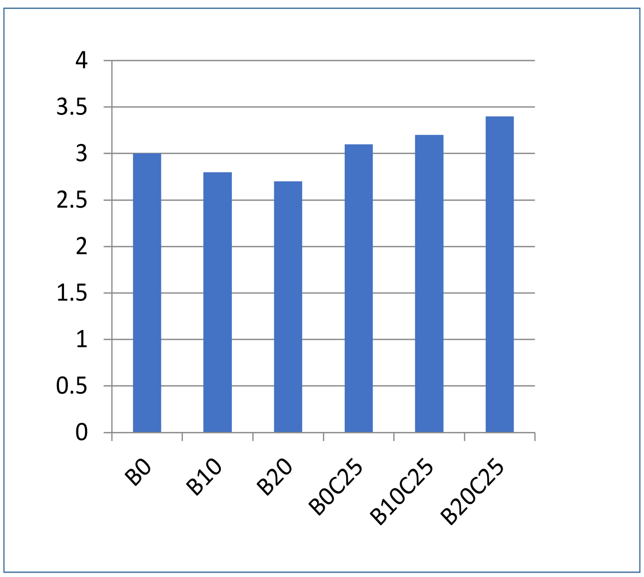

Figure 7. KV of various mixtures.

resistance of a fluid to flow when it is the only external force acting on it. This ratio calculates the density to the viscosity of the fluid.

Nanoparticles raise the mixes' KV, as can be seen in the plotted curve for biodiesel mixing. When nanoparticles are combined, KV always increases, however it can occasionally drop.

4.2 Performance Test of Engine

a. BTE: This could offer conclusive evidence that heat energy can be transformed into mechanical power. If the brakes are strong enough or durable enough, that is possible. BTE=BP/(fluid-mass*CV).

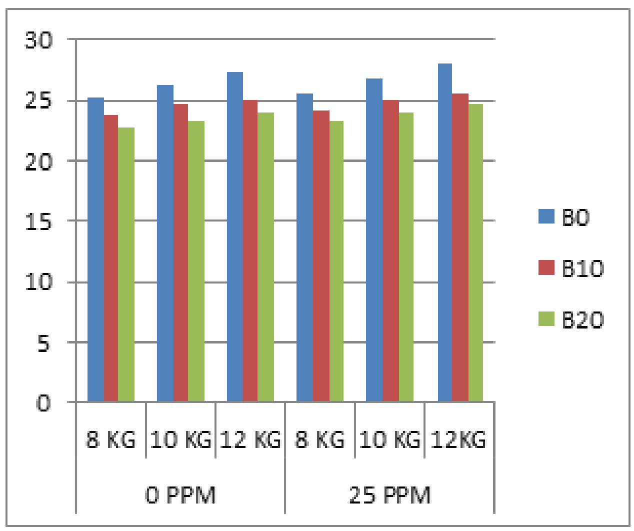

Figure 8. BTEVs load.

Table 4. BTE of the distinctive mixture on distinctive loads

CR 14	0 PPM			25 PPM		
	8 KG	10 KG	12 KG	8 KG	10 KG	12KG
B0	25.15	26.3	27.4	25.515	26.721	28.001
B10	23.84	24.6	25.1	24.166	25.101	25.627
B20	22.82	23.24	23.94	23.332	24.009	24.682

Table 5. BSFC of the distinctive mixture on distinctive loads

CR 14	0 PPM			25 PPM		
	8 KG	10 KG	12 KG	8 KG	10 KG	12KG
B0	0.3	0.287	0.275	0.245	0.266	0.254
B10	0.324	0.311	0.303	0.281	0.299	0.272
B20	0.356	0.343	0.322	0.336	0.323	0.302

BTE continues to improve when CNT nano-particles are added to various blends under heavy loads.

b. KBSFC: An engine uses BSFC worth of fuel to create one unit of energy. The amount of fuel required to create a driving unit is referred to as engine-specific energy consumption. BSFC = BP/ (FC*CV)

The BSFC is dropped if nanomaterials are added to the fuel. When nanomaterials are added to fuel, the value of the BSFC at peak load steadily drops.

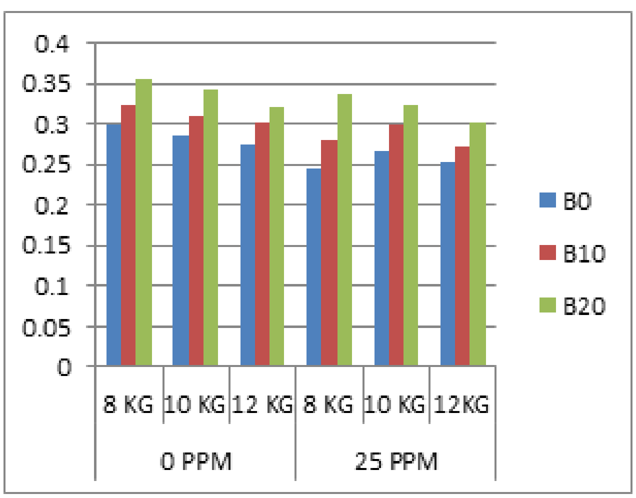

Figure 9. BSFCVs load.

4.3 Emission Test of Engine

a. Carbon Monoxide Emission[mg/nm^3]: Even though CO is a very little trace gas, its effects on the climate extend beyond their immediate effects. The amounts of CO_2, CH_4, and tropospheric ozone are all affected. Coal monoxide, like many other poisons, can come from sources that are both synthetic and natural.

b. Explanations for why different formulations' performance and emissions improved after combining MWCNTs:MWCNTs exhibit higher enzymatic activity due to their distinct chemical and physical properties. MWCNTs have been employed in nano form, which improves fuel economy and leads to a significantly reduced amount of combustibility by giving the fuel a lot larger surface area to burn on.

Table 6. CO emission of the distinctive mixture on distinctive loads

CR14	0 PPM			25 PPM		
	8 KG	10 KG	12 KG	8 KG	10 KG	12KG
B0	0.5	0.47	0.43	0.455	0.421	0.387
B10	0.43	0.41	0.39	0.385	0.365	0.346
B20	0.39	0.37	0.35	0.347	0.328	0.310

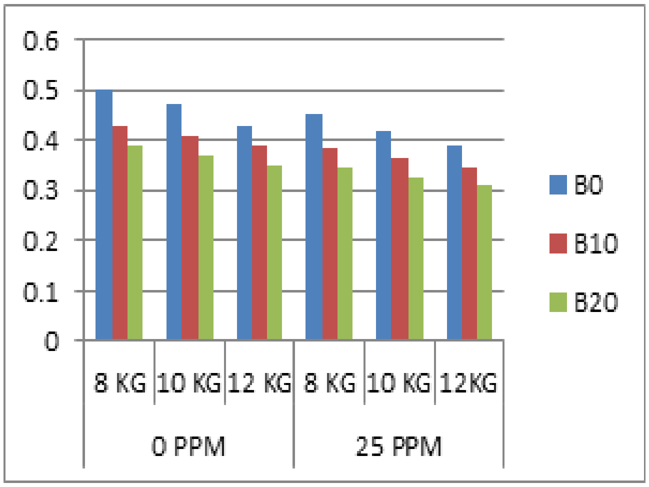

Figure 10. CO Vs load.

5.0 Conclusion

Inferring from the experiment, conclusions will be made.

1. With MWCNTs 25 ppm in B-20, the maximum CV is reported at 43002 KJ/kg weight, compared to 42698 KJ/kg for diesel.
2. Whilst for diesel it is 3Cst, the blend B-20 with MWCNTs25 ppm, has the greatest KV achieved at 3.4Cst.
3. The greatest BTE is 28.001% when comparing blend B-0 with CNT nano particles-25ppm, to diesel at a 12-kilogramme load.
4. The mix of B-0 with C-25 ppm has a lower BSFC of 0.254 kg when compared to plain diesel with a 12-kilogramme load.
5. The lowest CO emission is 0.310 mg/nm^3 when comparing B20 with C25ppm to B-0 at 12 kg load.

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