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# Investigation on Performance and Emission Indices of Coconut Oil Biodiesel/MWCNT/n-Octanal Blends in Water Cooled Compression Ignition Engine

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**Abstract:** Petroleum products such as petrol and diesels are being used as a fuel to the running of Internal Combustion Engines. Day by day demands for the petroleum products is increasing since its rate of consumption is increasing. If the trend will continue the whole world may suffer from shortage of petroleum products. Therefore, it is necessary to find different ways of reducing fuel consumption and at the same time to improve the performance of IC engine; it is necessary to find out some additives to mix it with the mixture of petroleum product and alternative fuel and one can formulate a new fuel. So, the project's focus is given to improve the performance of CI engine using diesel a The tests are run at 1500 rpm with varying loads on the diesel, cottonseed oil, n-Octanol and multi walled Carbon nano tubes (MWCNT) mixtures. i.e., BM1(Diesel 75%+ Coconut oil biodiesel 20%+ n-Octanol 5%), BM2(Diesel 75%+ Coconut oil biodiesel 20%+ n-Octanol 5%+ MWCNT 25ppm), BM3(Diesel 75%+ Coconut oil biodiesel 20%+ n-Octanol 5%+ MWCNT 50ppm), BM4(Diesel 70%+ Coconut oil biodiesel 20%+ n-Octanol 10%), BM5(Diesel 70%+ Coconut oil biodiesel 20%+ n-Octanol 10%+ MWCNT 25 ppm), BM6(Diesel 70%+ Coconut oil biodiesel 20%+ n-Octanol 10%+ MWCNT 50ppm). The findings indicate that incorporating cottonseed oil leads to an improvement in brake thermal efficiency, along with a decrease in specific fuel consumption and exhaust gas temperature. By increasing the amount of cottonseed oil in the blend, the emission parameters such as CO, CO2, NOx, and O2 are reduced, while HC emissions increase. Adding n-octanol and graphene to the cottonseed oil blend diesel fuel has a comparable impact to adding pure cottonseed oil in different proportions. This leads to an increase in brake thermal efficiency, a decrease in specific fuel consumption, and a reduction in exhaust gas temperature.

**Keywords**: Coconut oil biodiesel; n-octanol; MWCNT; Performance; Emission

## 1.Introduction:

The diesel power unit has many benefits, such as a broad variety of compression ratios, fuel flexibility, and fuel-lean operating. Additionally, it has a charging mode that is un throttled. However, they are still impacted by the conventional NOx vs. smoke emission tradeoff[1]. Greater injection pressures, enhanced combustion chamber design, complicated after-treatment systems, variable valve timing, and high EGR concentrations (>40%) have all contributed to diesel technology's meteoric rise since the California Air Resources Board's 1968 founding. In order to achieve the stringent emission requirements, it is necessary to add electronic controls, upgrade the engine's hardware, and implement post-treatment operations [2]. Equally enticing are the tactics for fuel management that reduce engine-out pollutants. Due to its relatively simple composition (four to eight main methyl ester components), biodiesel is an easier alternative fuel to get your hands on [3]. Saturated methyl esters with single bonds, such laurate and stearate, tend to improve the rating of biodiesel fuels [4]. This is in contrast to unsaturated methyl esters with double bonds, like linoleate and oleate, which increase the degree of unsaturation. If you're using a diesel engine and don't want to mess with the engine's hardware, B20 is the recommended blend proportion. A target of 5% biodiesel and 20% ethanol blends in fuel has been established by the Indian transportation industry [5]. The power and torque produced by B20 engines are comparable to those of diesel engines [6]. Previous studies indicated that B20 operating increased fuel consumption by 2.4%, which is a significant rise for an Indian nation like India. According to reports, the main drawback of utilizing biodiesel is its higher fuel consumption and NOx generation compared to fossil diesel [7]. There have been several attempts to decrease NOX emissions, including selective catalytic reduction, low-temperature combustion, modified kinetics, lean NOX traps, and others. [8]. Researchers have focused on emulsification [9], nano additives [1] and n-octanol [3] as fuel side solutions to lower biodiesel-NOx emissions. To decrease the amount of unsaturated components, the hydrogenation thermochemical process entails adding hydrogen gas to a fuel reactor with a catalyst while keeping the pressure and temperature constant. Catalysts composed of palladium, platinum, nickel, and copper are used in hydrogenation. To improve cetane and reduce exhaust NO emission, the polyunsaturated ester groups in biodiesel fuel may be partially hydrogenated [10]. Consequently, this study found that the use of hydrogenated Karanja biodiesel decreased NO emission. The performance of the BSFC with B20 is being improved by combining hydrogen induction with intake air [1]. I.C. engines benefit greatly from hydrogen due to its reduced molecular weight and greater energy content [11], [12]. Many studies have linked the usage of hydrogen in the dual fuel mode to an increase in engine output, as seen in Table 1.

For their 2018 study, Atmanli and Yilmaz [13] added six different binary fuel mixtures to diesel fuel, each containing n-butanol and n-pentanol. Five percent, twenty-five percent, and thirty-five percent of the gasoline mixtures were tested. Performance metrics and NOx emissions were both significantly reduced (14.27% reduction) when 35% n-pentanol was added to the diesel fuel sample. Nour et al. (2019) found that at higher alcohol concentrations (10 and 20%) in diesel, n-butanol causes an ignition delay [14]. By including n-Heptanol into the diesel mixture, the highest heat release rate (HRR) was achieved while simultaneously reducing emissions of smoke and NOx. Research conducted by El-Seesy, A. I et al. (2020) [15] found that diesel fuel containing graphene oxide (GO) nanoparticles and higher alcohols considerably decreased emissions of CO, UHC, and smoke. Also, HRR and CP showed improvement. Nothing has changed with the nitrogen oxide levels. A study conducted by EL-Seesy, A. I et al. (2020) [16] shown that adding higher alcohols such as n-butanol, n-heptanol, and n-octanol to the jojoba-diesel combination effectively reduces NOx formation. Adding C3, C4, and C5 alcohol blends improved the low-temperature performance of biodiesel-diesel blends made from spent cooking oil, according to a separate study by Atmanli and Yilmaz (2020) [17]. As the alcohol percentage increased relative to pure biodiesel, performance degraded and CO and NOx emissions decreased. Investigating the effects of various additives on the efficiency of a jatropha biodiesel-diesel blend was the major objective of the research conducted by El-Seesy, A. I. et al. (2021) [18]. The study found that adding n-octanal increased Brake Thermal Efficiency (BTE) by 10% and adding n-butanol increased it by 13%. For optimal BTE, use a mixture of biodiesel and diesel that has MWCNT added to it. Increases in alcohol content result in 30, 20, and 40% reductions in CO, HC, NOx, and smoke, respectively. Incorporating MWCNT nanoparticles into biodiesel-diesel blends also significantly lowers NOx levels by 13%. Research by Nour, M et al. (2021) [19] found that ternary mixtures enhanced vaporization and combustion. Diesel that was supplemented with n-butanol and n-heptanol decreased smoke by 38%, NOx by 11%, CO by 35%, and CO2 by 14%.

Using biodiesel-diesel blends with hydrogen enrichment combined clearly improved performance and combustion characteristics. Incorporating nanoparticles and hydrogen enrichment into biodiesel-diesel blends enhances performance while reducing emissions, with the exception of nitrogen oxides (NOx) pollutants [20]. However, there is a lack of data on the potential benefits of diesel-biodiesel blends including oxygenated n-butanol alcohol for CI engines in terms of reducing NOx output. No studies have investigated the use of n-butanol alcohol and carbon allotropes (G) to improve a Biodiesel-diesel blend as of yet [21]. Therefore, this study aims to examine how using nanoplatelets in combination with oxygenated n-Butanol in biodiesel-diesel blends and hydrogen enrichment impacts the efficiency, combustion, and emissions of a 4-stroke, single-cylinder CI engine.[22].

I am motivated by the fact that many recent studies have shown that the combination of additives, diesel, and biodiesel increases NOx levels owing to the viscosity and heating value problems that these mixes cause. To address these issues, substantial engine modifications are required [23]. But combustion using compressed ignition technology is intricate and reliant on many different things interacting with one other. A lot of scientists are very interested in how EGR, ignition delay, compression ratio, and fuel injection pressures all work together [24]. Previous studies have also indicated promising outcomes from careful fuel selection. Adding novel ingredients, such as higher alcohols and nano additions to diesel and biodiesel, has shown to be an effective solution to the problem of renewable fuels failing to meet strict emission standards for existing engines without modifications.

## 2 Materials & Methods

### 2.1 Coconutoil oil methyl ester, COME

The three-step technique that follows in order to extract COME includes oil-Oil extraction, esterification, and transesterification are the three steps that make up the COME extraction process. The following methods for extracting oil were thoroughly examined. After being dried to remove any moisture, the cotton seeds were ground into oil using seed crushers. A series of filters are used to remove any solid contaminants from the raw oil. It takes 30 minutes to get the raw oil up to 120 degrees Celsius. Eliminating the saponification reaction is one benefit of preheating [25]. The presence of free fatty acids and moisture may effect the output of biodiesel, therefore understanding their significance is vital. Soap is formed when alkali catalysts interact with free fatty acids, reducing the biodiesel output. The esterification procedure is carried out using 99% pure Merc sulfuric acid to keep the original oil's FFA concentration below 0.6%. Esterification involves adding a combination of sulphuric acid and methanol to the raw oil in precise amounts. The next step is to heat the mixture up while maintaining a constant state[1], [26]. The chilling procedure initiates the transesterification process once the esterified bath has been created. As part of this procedure, the bath is amended with methanol (in a molar ratio of 1:8) and KOH (in a volume-to-volume ratio of 1%). Like the preceding reaction, this one also makes use of the same heating circumstances. The result is COME, which is greenish-yellow in hue. Equation 1 shows the transesterification process, and table 1 contains the characteristics.

$$RCOOR' + R''O \xrightarrow{KOH} RCOOR'' + R'' \quad (1)$$

**2.1 Pilot fuel preparation and their properties**: The experiment involves preparing pilot fuel and studying its qualities. An agitator is used to combine a certain quantity of n-Octanol (5%), 20% COME, and 75% petrodiesel in a solution. After a full hour of vigorous stirring, the mixture is designated BM1. To obtain a homogenous mixture, the nano MWCNT (25 mg/litre on mass basis) is physically mixed with BM1 and then ultrasonicated for around two hours. To make BM2, the mixture is placed into the agitator and left for two more hours to make the pilot fuel more stable. Also, using the specified volumes of basic fuels and additives, more pilot fuels are made. When nanoparticles are present, it becomes very important to make sure the pilot fuels are stable. This research examines the nano-fuels' stability by means of the direct sedimentation method. We did not detect any silt particles or phase separation after meticulously monitoring all nano-fuels for more than a week. The several pilot fuels that were considered for this research are listed below.

BM1: 20% COME + 5% n-Octanol+75% Petrodiesel

BM2: 20% COME + 5% n-Octanol+ 25 ppm MWCNT +75% Petrodiesel

BM3: 20% COME + 5% n-Octanol+ 50 ppm MWCNT +75% Petrodiesel

BM4: 20% COME + 10% n-Octanol +70% Petrodiesel

BM5: 20% COME + 5% n-Octanol+ 25 ppm MWCNT +75% Petrodiesel

BMf6: 20% COME + 10% n-Octanol+ 50 ppm MWCNT +75% Petrodiesel

**2.2 Experimentation:**

Here is an example of sequential testing in action. As a first step, the test rig is traditionally heated with petrodiesel fuel for around 10 minutes. The next step is to transfer the fuel line to the pilot fuel. The load detecting valve allows the engine to be changed in relation to the load. In the end, data is gathered from various devices after they have reached a steady condition. It is important to maintain a steady-state condition in this investigation because the exhaust gas temperature remains stable within ± 1°C. All test fuels undergo the same procedure under varied load situations. The fuel line is changed to petrodiesel when the experiments with a pilot fuel are finished. After that, the test engine is given ten minutes to operate without any load. As a result, the injection system is kept clean and thermal cracking is avoided. Using a range of pilot fuels, the test engine's performance characteristics and emission profiles are examined. The experimental test engine's architecture is shown in Figure 1, and the specs that were exhibited are showcased in Table 2.

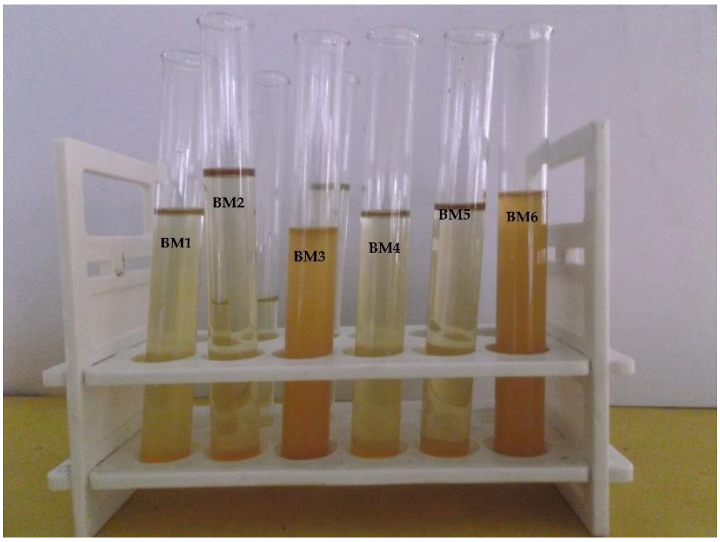


**Fig 1: Test samples**

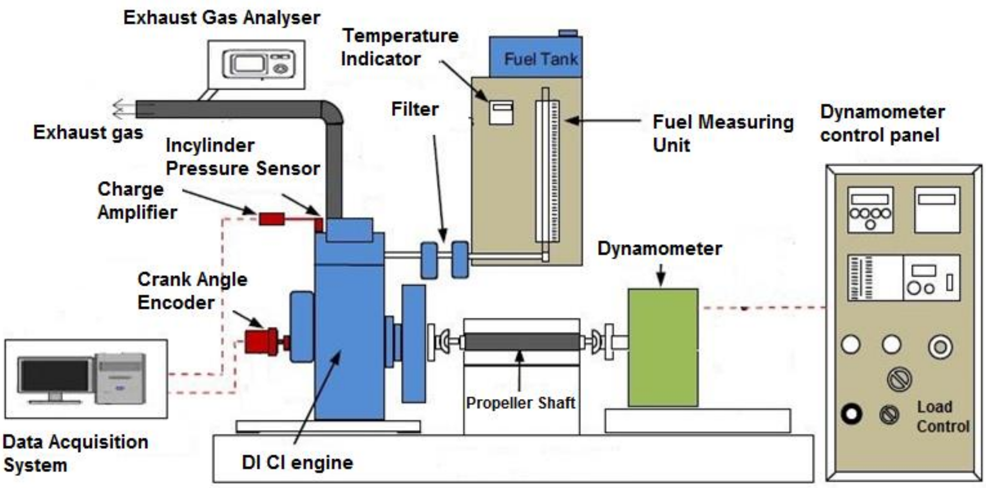


**Fig 2. Schematic diagram of Engine setup**

**Table 2. Test rig specifications [1]**

| Sl. | Engine Components | Specifications |
|---|---|---|
| 1 | Make | Kirloskar Oil Engine Ltd. |
| 2 | Model | TV1 |
| 3 | No. of Cylinders | 1 |
| 4 | No. of Strokes | 4 |
| 5 | Bore Dia. | 87.5 mm |

| | | |
|---|---|---|
| 6 | Stroke Length | 110 mm |
| 7 | Compression Ratio | 17.5 |
| 8 | Cylinder Volume | 661 cc |
| 9 | Cooling System | Water Cooled |
| 10 | Fuel Oil | H. S. Diesel |
| 11 | Lub. Oil | SAE 30/SAE 40 |
| 12 | Fuel Injection | Direct Injection |
| 13 | Governing | Class "B1" |
| 14 | Start | Hand Start |
| 15 | Rated Output | 3.5 kW |
| 16 | Rated Speed | 1500 RPM |
| 17 | Overloading of Engine | 10% of rated output |
| 18 | Lub.Oil Sump Capacity | 3.7 Lt |
| 19 | Injection pressure | 205 bar |

**2.3 Uncertainty Study:**

The experimental uncertainty condition was strongly related to the employment of several instrumental rigs, such as flue gas analyzers, flow meters, and loading equipment. The uncertainty associated with various entities and the tools used to measure them are shown in Table 5. Devices for measuring flow, such as eddy current dynamometers and crank angle encoders, are part of this apparatus. This analysis used the RMS technique, and the findings of the mathematical computation of the total percentage uncertainty δX are shown in Equation 2 below [27].

$$\delta X = \sqrt{\left\{\begin{matrix} (flowmeter_{water})^2 + \left(Loader_{Eddycurrent}\right)^2 + (Sensor_{Load})^2 + (Speed)^2 \\ + \left(Pressure_{Cylind}\right)^2 + \left(Sensor_{angle}\right)^2 + (Fuelguage)^2 + (flowmeter_{air})^2 \\ + (calorific\ value)^2 + (Exhaust_{NOx})^2 + (Exhaust_{CO})^2 + (Exhaust_{HC})^2 \end{matrix}\right\}} \quad (2)$$

$$\delta X = \sqrt{\left\{\begin{matrix} (0.12)^2 + (0.1)^2 + (0.2)^2 + (1)^2 + (0.05)^2 + (0.2)^2 + \\ (0.2)^2 + (0.075)^2 + (0.05)^2 + (0.9)^2 + (0.05)^2 + \\ (0.05)^2 + (0.1)^2 \end{matrix}\right\}} = 1.407$$

**3. Results and Discussion:**

**3.1 Performance**

**3.1.1 BSFC**

Idle speeds were the optimal range for BFSC, or brake specific fuel consumption, which is defined as the quantity of fuel needed to generate one unit of power. Almost every fuel sample tested, including base fuel diesel, showed this optimum value. But when they raised the engine brake power, they saw a declining trend. With a particular fuel consumption of 250 kg/kWh, the BM3 mix achieved the lowest BSFC recorded, 4.6% lower than diesel and 2.1% lower than the next lowest BM6 blend. [28]. BM6's figure was 2.54 percent lower than diesel's. Diesel has a lower calorific value and a greater viscosity, but BM4 mix has a maximum brake specific fuel consumption that is 0.872% higher. The samples' lower energy density is sufficient to provide the same amount of power as base fuel diesel, which is the rationale for this.(As shown in fig 3.1).

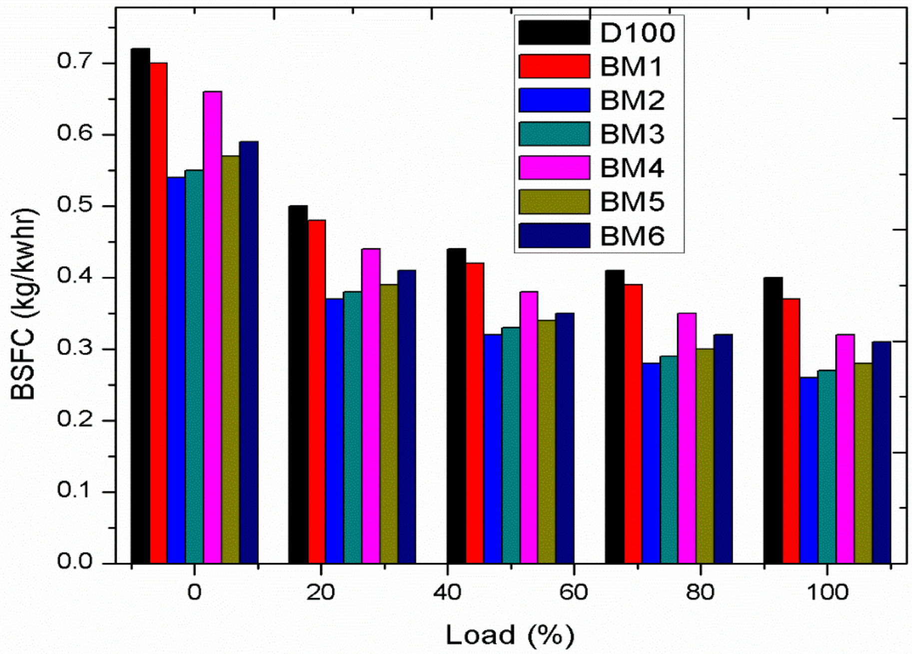


**Fig 3.1 :BP Vs BSFC**

**3.1.2 The Brake thermal efficiency (BTh)**

In Figure 4.2, we can see the relationship between engine brake power and brake thermal efficiency (BTh) for different mixes. Compression ratio, fuel-air ratio, fuel characteristics, and fuel combustion all play a role in determining the BTh of a compression ignition diesel engine. In comparison to engine BP, BTh has grown substantially. Fuel buildup within the cylinder, brought about by increased fuel supply to the engine under heavier loads, reduced the slopes of the curves. [29] The highest BTh value of 31.37% was achieved in the BM3 blend, which is 6.12% more than diesel because biodiesel, diesel, and alcohol blends have higher heating values. After BM3, the mix that gained the most BTh was BM6, which was 4.17 percent more than diesel and 5. 5 percent less than BM3. Because of the additive's ability to promote full combustion and the biodiesel's high oxygen concentration, this occurred. (Referring to figure 3.2)

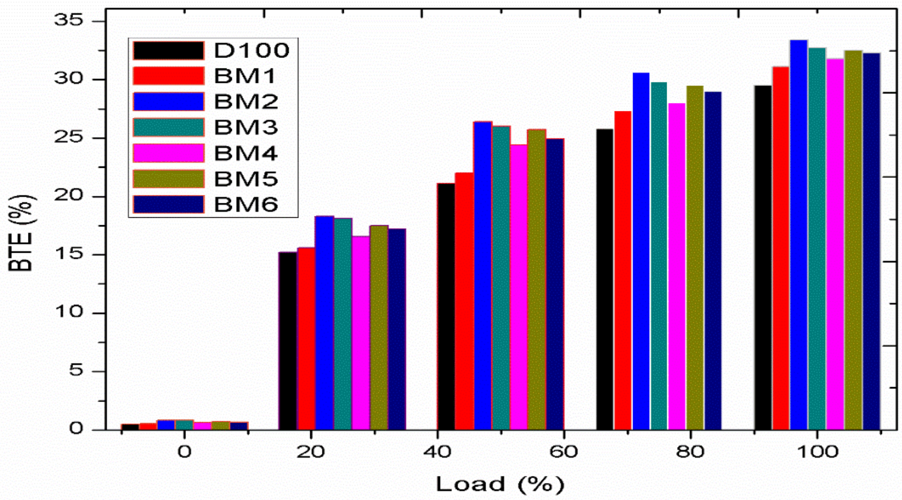


**Fig 3.2 :BP Vs BTE**

### 3.2 Emissions

#### 3.2.1 Carbon monoxide (CO)

Figure showing carbon monoxide with BP variation for various fuel mixtures. Since a greater quantity of charge induction requires less time to burn entirely, CO emissions are greater with higher engine braking power levels. The graph clearly shows that compared to the basic fuel diesel, all of the tested fuels had lower CO levels. Biodiesel and higher alcohols accelerated CO oxidation due to their increasing oxygen content. However, CO emissions were somewhat higher in the gasoline samples treated with MWCNTs. [30]. This is because the oxidation of CO has been reduced. When compared to diesel, the biodiesel mix BM4 produces 31.47 percent less value, while BM1 produces 22.7 percent less. Following the incorporation of the ignition improver BM2, BM3's output increased by 2.19% compared to BM1 and decreased by 22.25% compared to diesel. The emissions produced by Bm4 are 31% less than those of diesel. Production is 2.13 percent higher than BM4 and 30.33 percent lower than diesel with the addition of ignition improver BM5. (Referring to figure 3.3)

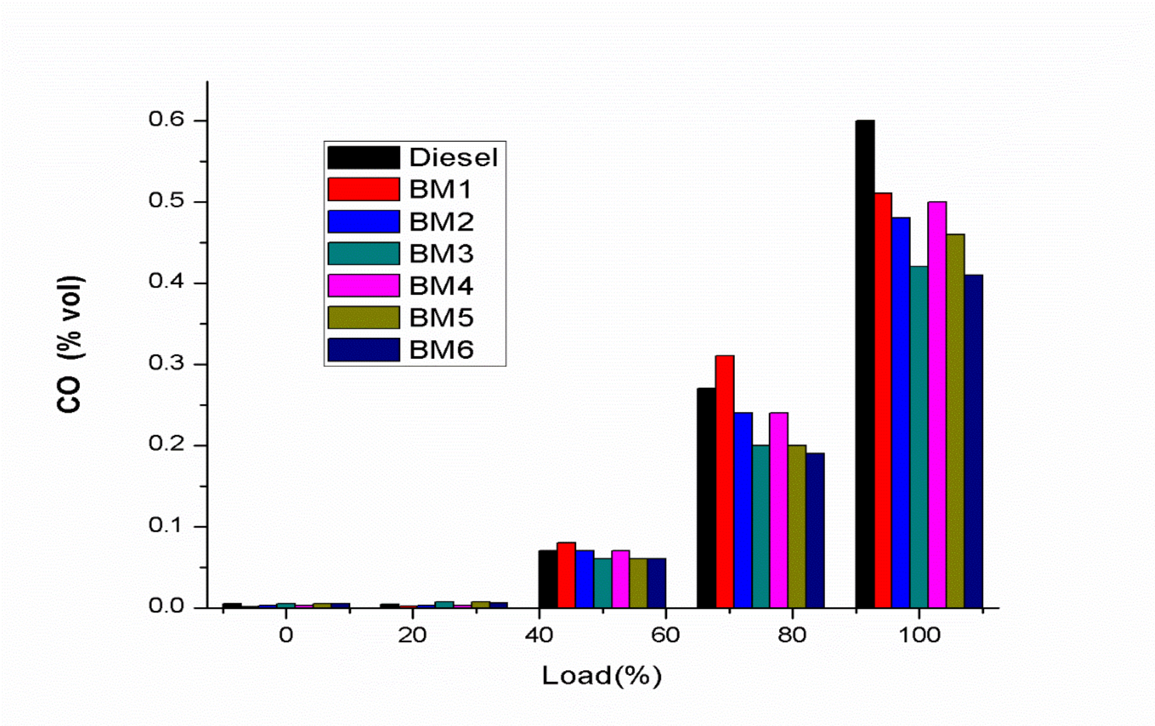


**Fig 3.3 :BP Vs CO**

#### 3.2.2 Unburnt Hydro Carbon (UHC)

Figure showing carbon monoxide with BP variation for various fuel mixtures. The amount of unburned hydrocarbon emissions increases as the engine braking power increases in almost all of the test samples, including the base fuel diesel. When contrasted with diesel, the base fuel, it revealed a declining tendency for all of the test fuels [31]. It is easy to see from the graph how biodiesels might be beneficial and how additions with increased alcohol content are often used. Minimum UHC (23% and 29%, respectively) was observed in the alcoholic biodiesel blends BM1 and BM4, in comparison to diesel. While MWCNTs improved diffusion combustion and slowed down CO oxidation, they also increased unburnt hydrocarbons. When compared to base fuel diesel, BM2, BM3, and BM5 all demonstrated 27%, 23%, and 24.5 % reductions in emissions, respectively. Compared to BM1, BM2 and BM3 had 1.4% and 6.3% higher emissions, respectively, while BM5 and BM6 exhibited a 3.1% and 6.7% increase, respectively, over BM4. Because MWCNTs has a multiplicative effect on air-fuel mixing, they shorten the pre-mixed combustion period and, in turn, increase the number of UHC values by extending the diffusion combustion process. As seen in figure 3.4

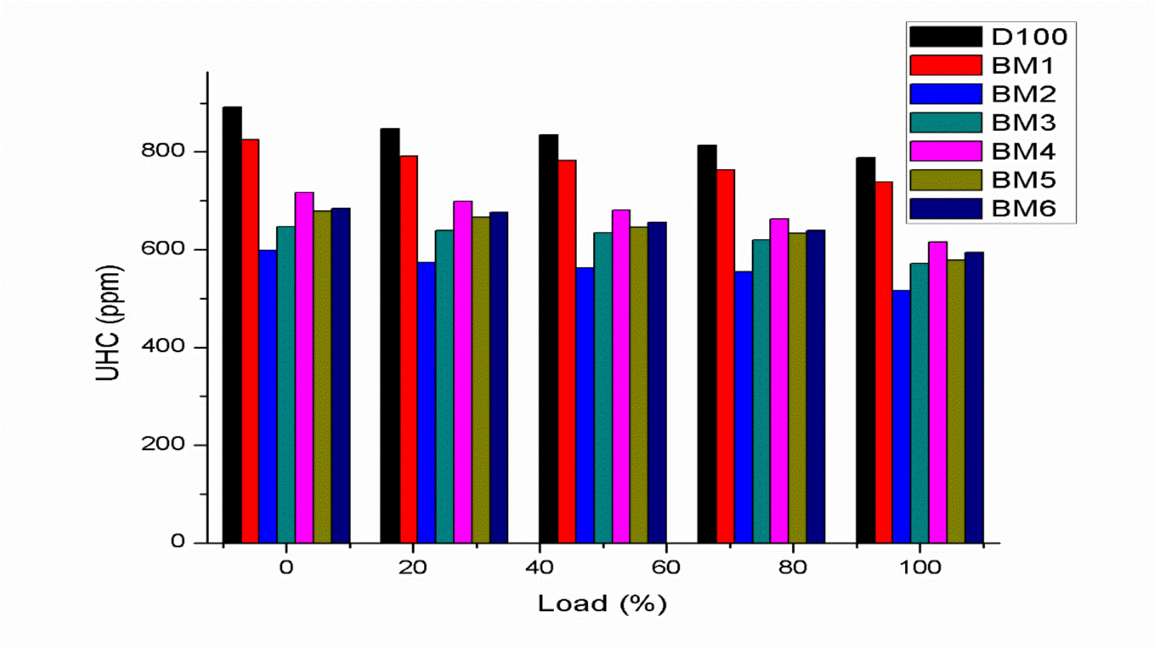


**Fig 3.4 :BP Vs HC**

### 3.2.3 NOx emissions

A gasoline sample's cetane index determines its NOx emissions. Nox levels are lowered because gasoline with a higher cetane index has a shorter ignition delay. The graph clearly displays the functional drawback of the alcohol treated fuel samples, as shown by the higher NOx levels. Since a greater cetane index increased the total cetane index of the samples, this graph illustrates the possible advantages of an ignition promoter like MWCNT. Combustion begins early, resulting to greater pressures and temperatures, which in turn limits NOx, and fuels with a higher cetane index go hand-in-hand with reduced premixed combustion. A rising trend with engine braking power is seen in all fuel samples, including diesel [32]. When compared to diesel, the alcoholic biodiesel samples BM1 and BM4 produce 2% and 4% higher NOx, respectively. However, as compared to baseline fuel, BM2, BM3 produce 1% and 2.1% less NOx, respectively, while BM5, BM6 produce 0.47% and 1.7% less NOx, respectively, due to the inclusion of ignition improver. When compared to diesel, the BM3 figures are quite promising. The fact that MWCNT has a lower vapour pressure makes it an effective charge coolant, which in turn reduces Nox. As seen in figure 3.5

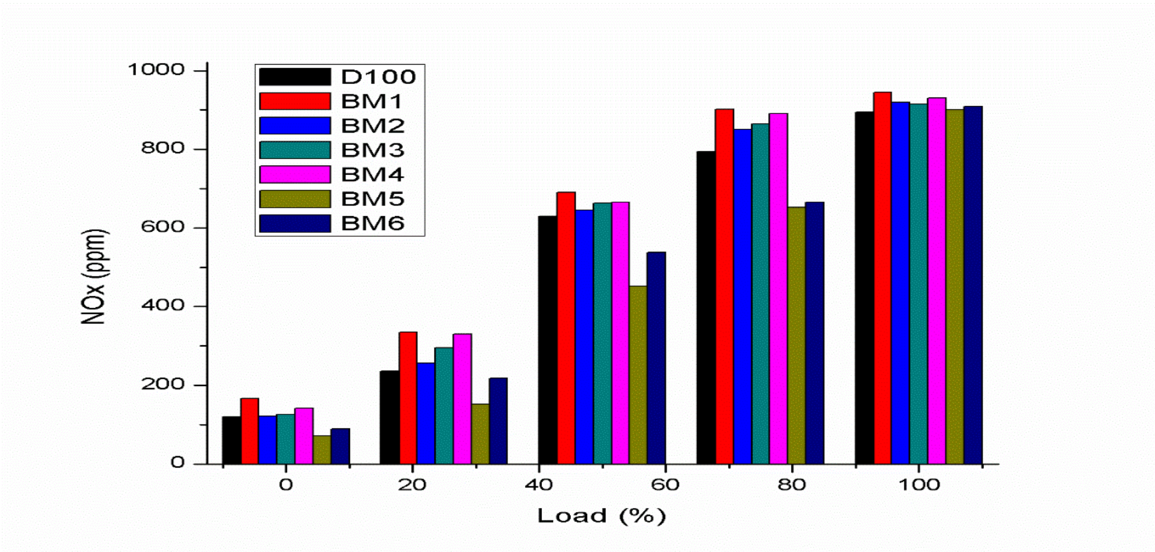


**Fig 3.5 : NOX Vs BP**

**4. Conclusion:**

Experimental results on a single-cylinder, water-cooled CI engine were compared for the efficiency and pollution levels of diesel, biodiesel, and standard diesel blends. The results of this full-load study are as follows:

Boosts in brake thermal efficiency are proportional to increases in biodiesel content. The biodiesel-diesel-MWCNT combination achieved the best brake thermal efficiency of 31.47%, thanks to the greater heating values compared to diesel. Actually, it's 5.27 percentage points more than diesel. The MWCNT concentration of biodiesel is the only reason why the fuel burns completely in it.

A maximum reduction in CO emissions of 31.47 percent is achieved when biodiesel blend 4 is compared to regular fuel. The other blends of biodiesel show a less pronounced reduction in NOx emissions compared to diesel, whereas blend 3 shows a substantial but slight drop of 1.9%. In both BM1 and BM4, the emissions of unburned hydrocarbons decreased by 24% and 29%, respectively. In comparison to the other mixes, it showed the smallest reduction in hydrocarbons.

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