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# Assessment of Performance and Emission Characteristics of Biodiesel/Graphene/ N-Octanal Blends in Water Cooled Compression Ignition Engine

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***Abstract:** Biodiesel and alcohols are only two of the numerous alternative fuels that have found widespread commercialization in the transportation and industrial sectors. Cottonseed oil and n-octanol piqued our curiosity again in this regard. The engines used in the experiments are single-cylinder four-stroke diesel engines with a power output of 1.5 kW. The tests are run at 1500 rpm with varying loads on the diesel, cottonseed oil, and graphene mixtures. i.e., BB1(Diesel 75%+ Cottonseed biodiesel 20%+ n-Octanol 5%), BB2(Diesel 75%+ Cottonseed biodiesel 20%+ n-Octanol 5%+ nanographene 25ppm), BB3(Diesel 75%+ Cottonseed biodiesel 20%+ n-Octanol 5%+nanographene 50ppm), BB4(Diesel 70%+ Cottonseed biodiesel 20%+ n-Octanol 10%), BB5(Diesel 70%+ Cottonseed biodiesel 20%+ n-Octanol 10%+ nanographene 25 ppm), BB1(Diesel 70%+ Cottonseed biodiesel 20%+ n-Octanol 10%+ nanographene 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**: Cottonseed oil, n-octanol, Graphene, Performance, Emission*

## I. INTRODUCTION

Conventional oil and gas have great potential as an important energy source, propelling national economies throughout the globe. Consequently, oil prices skyrocket due to the massive demand caused by the rapid depletion of these fossil resources caused by their broad usage [1]. The majority of fossil fuels are used in several industries, including transportation and industrialization [2][40][41][42]. But transportation and motorization are the most common uses of fossil fuels. Compression ignition (CI) engines are vital in transportation because of their high-power output and excellent fuel economy [3]. Their primary function is to transport goods from one location to another [4]. On the other hand, CI engines are known to emit dangerous pollutants that threaten the environment and human health. These pollutants include carbon dioxide, particulate matter, ozone depletion, and air pollution. Rapidly shifting away from fossil fuels and toward more sustainable alternatives is critical in light of the current crises and their far-reaching effects [5,6].

Research toward a renewable, eco-friendly, and pollution-free diesel substitute started in this setting [7]. Because it is made from several sources, including waste oils and vegetable oils, biodiesel is seen as a very promising substitute. Fuels such as biodiesel are produced by combining crude oil with alcohol and a catalyst. Reducing emissions and promoting sustainability are two of its well-known characteristics. Easy availability, reasonable cost, and compatibility with biodiesel production should all be considered while choosing a feedstock for biodiesel [8]. In this study, "Sterculia foetida" was selected as the non-edible feedstock for biodiesel production. The feedstock is a mixture of fifteen to twenty pale tree seeds. There are several benefits to using Sterculia foetida seed oil as a feedstock for biodiesel production due to its high oil content (50-60%). Biodiesel, on the other hand, is a popular and highly sought-after alternative to diesel fuel for engines since it has the same energy content, fuel economy, and cetane number [8]. Furthermore, the higher oxygen concentration leads to a decrease in emissions [9]. The use of biodiesel is not without its limitations, however. Issues including carbon buildup, poor performance, increased fuel consumption, and fuel injector blockage might occur due to its lower heating value, greater viscosity, and density [10]. Nevertheless, a notable study gap that has remained over the last 2-3 decades has been the finding that CI engines powered by biodiesel emit more nitrogen oxide, or NOx, [3,11].

Research in medicine, the automotive sector, and biotechnology are just a few of the many areas that find use for nanoparticles [12].

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Their increased catalytic activity, better surface-to-volume ratio, and improved thermal, optical, and conductive properties all work together to improve combustion, emissions, and performance [13]. In order to improve engine performance, researchers have used biodiesel blends that include nano additions of different metals and metal oxides. A few examples of these additions include cobalt, boron, copper, iron, titanium oxide, and aluminum. Further acceleration of the fuel spray jet's velocity improves secondary atomization. Nanoparticles come in many forms, but carbon allotropes have recently been all the rage because of their organic makeup, low environmental impact, and potential to lessen harmful emissions [14]. Carbon nanoparticles called graphene nanoplatelets (G) improved performance and reduced emissions when used as a catalyst for combustion. The present investigation treats the G as an additive. Das, S., & Das, B. (2023) [15] investigated the effects of adding iron nanoparticles to biodiesel samples made from used cooking oil. The authors are experts in the field of energy efficiency. A common rail direct injection (CRDI) engine was also used, along with hydrogen gas enrichment operating at a 10 lpm flow rate. The most important results show a 7.1% improvement in BTE and a lower BSFC compared to diesel. However, CO emissions dropped by 37.5% and HC emissions dropped by 41.8%. Nonetheless, emissions of nitrogen oxides rose little. In contrast, there is a 5.3% improvement in CP combustion characteristics and a 6.7% increase in HRR combustion characteristics. Suhel A et al. (2021) [16] tested a DI, water-cooled CI engine in a different investigation. B20, a combination of chicken fat biodiesel and diesel, was employed, along with 100 ppm of magnetic nanoparticles. Ten and fifteen liters per minute of hydrogen gas were also added. Improved energy efficiency and reduced emissions of smoke, CO, NOx, and HC were shown by the findings. Researchers found that diesel and biodiesel mixes with nanoparticles had better combustion characteristics and better secondary atomization, leading to less harmful emissions. Murugesan P et al. (2022) [17] investigated the impact on HCCI and CI engines by using graphene oxide biodiesel-diesel blends including Euglena Sanguinea at various dosage levels (20, 40, 60, and 80 ppm) in addition to hydrogen gas in a distinct research. The HCCI engine is able to decrease emissions of HC, CO, smoke, and NOx while simultaneously improving performance. Adding 100 ppm $TiO_2$ to biodiesel-diesel blends produced from waste cooking oil and enriching them with $H_2$ at a flow rate of 5 lpm improved several features, according to a different research by Zhang X et al. (2022) [18]. Brake specific fuel consumption (BSFC) was decreased, brake thermal efficiency (BTE) was raised, emissions of CO, $CO_2$, and HC were decreased, and emissions of NOx were slightly increased.

Recent studies have shown that biodiesel-diesel nanoparticles may improve performance characteristics and reduce pollution when oxygenated alcohols, especially higher alcohols, are used as additives [19]. Because of the varying locations of the C-H bonds in these alcohols, combustion speed is increased and NOx generation is affected differently. This led to a decrease in NOx emissions and an increase in combustion rate [20]. El-Seesy, A. I., & Hassan, H. (2019) [21] discovered that a blend of 60% jatropha biodiesel and 40% n-butanol included GO, G, and multiwalled carbon nanotubes (MWCNT). The study found that BSFC dropped by 35% when diesel-biodiesel used oxygenated n-butanol. Using a biodiesel-n-butanol mix with CNTs also decreased emissions of nitrogen oxides (NOx), hydrocarbons (HC), and carbon monoxide (CO) by 55%, 45%, and 50%, respectively. The usage of n-butanol and nano additives successfully decreased NOx emissions. We were able to do this by maximizing the cetane number, decreasing the enthalpy fluctuation, and raising the oxygen level. A different group of researchers, J et al. (2019) [22], tested a CI engine with only one cylinder. They experimented with B10, B20, and B30 mixes of biodiesel and diesel made from waste vegetable oil, with and without n-pentanol added at 10% and 20% concentrations, respectively. According to the research, the mixes' enhanced performance led to lower CO, HC, and NOx pollution levels. The reason for this is because the B30 + 10% n-pentanol blend and the B10 + 20% n-pentanol blend both have lower cetane numbers. Separate research by Billa et al. (2018) [23] found that diesel with 5 to 10% n-octanol improved CP and HRR and reduced CO and NOx emissions. Another research came to a similar conclusion, finding that diesel with10%,20%, and 30% n-octanol and n-pentanol reduced HC and CO emissions. The addition of n-octanol to the diesel mixture increases the production of nitrogen oxides. The reason for this result is that n-octanol has a lower energy level and a larger latent heat of evaporation.

Adding six distinct binary fuel mixes comprising n-butanol and n-pentanol to diesel fuel was the subject of an investigation by Atmanli and Yilmaz (2018) [24]. Three distinct concentrations of the gasoline mixes were evaluated:5%,25%, and 35%. By adding 35% n-pentanol to the diesel fuel sample, the results show a significant drop in performance metrics and a fall of 14.27% in NOx emissions. Nour, M. et al. (2019) [25] discovered that n-butanol increases ignition delay when diesel has greater alcohol concentrations (10 and 20%). The addition of n-Heptanol to the diesel mix reduced smoke and NOx emissions and produced the maximum heat release rate (HRR). Diesel fuel containing graphene oxide (GO) nanoparticles and higher alcohols significantly reduced emissions of CO, UHC, and smoke, according to a different research by El-Seesy, A. I et al. (2020) [26]. Furthermore, they noted improvements in HRR and CP. Nitrogen oxide levels have not changed. Incorporating higher alcohols like n-butanol, n-heptanol, and n-octanol into the jojoba-diesel mixture will successfully decrease NOx generation, as shown in a research by EL-Seesy, A. I et al. (2020) [27]. The low-temperature performance of biodiesel-diesel blends produced from used cooking oil was enhanced by adding C3, C4, and C5 alcohol blends, according to a different research by Atmanli and Yilmaz (2020) [38]. Impaired performance and lower CO and NOx emissions were seen with increasing alcohol content as compared to pure biodiesel.

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El-Seesy, A. I. et al. (2021) [28] performed research with the primary goal of studying how different additives affected the efficiency of a jatropha biodiesel-diesel mix. According to the research, Brake Thermal Efficiency (BTE) was enhanced by 10% and 13% with the addition of n-octanal and n-butanol, respectively. Blends of biodiesel and diesel with GO added provide the best BTE. Adding more alcohols reduces CO, HC, NOx, and smoke by 30, 20, and 40% correspondingly. Also, NOx levels are reduced by a substantial 13% when GO nanoparticles are added to biodiesel-diesel blends. Ternary mixes improved vaporization and combustion, according to a different research by Nour, M et al. (2021) [29]. Supplementing diesel with n-butanol and n-heptanol significantly improved BTE and reduced NOx, CO, CO2, and smoke by 11%, 35%, 14%, and 38%, respectively. From what we can see, the performance and combustion characteristics were much enhanced when biodiesel-diesel blends with hydrogen enrichment were used together. With the exception of nitrogen oxides (NOx) pollutants, biodiesel-diesel blends that include nanoparticles and hydrogen enrichment further improve performance and decrease emissions. But few research have looked at how CI engines may benefit from diesel-biodiesel blends that include oxygenated n-butanol alcohol to cut down on NOx production. So far, there has been no research on enhancing a Biodiesel-diesel mix using n-butanol alcohol and carbon allotropes (G). Hence, the purpose of this research is to analyze the effects on the efficiency, combustion, and emissions of a 4-stroke, single-cylinder CI engine by using nanoplatelets in conjunction with oxygenated n-Butanol in biodiesel-diesel blends and hydrogen enrichment.

Motivation comes from the fact that several recent publications have shown that the mixture of diesel, biodiesel, and additives leads to increasing NOx levels due to the viscosity and heating value issues that these blends generate. Major engine upgrades are needed to fix these problems [30]. Combustion using compressed ignition technology is complex, however, and depends on a wide range of elements working in concert. There has been a lot of excitement among scientists on the combined impacts of EGR, ignition delay, compression ratio, and fuel injection pressures [31]. Careful fuel selection has also shown potential results in prior research. To tackle the issue of renewable fuels not fulfilling stringent emission regulations for current engines without changes, a very successful option has been to add new inventions like higher alcohols and nano additions to diesel and biodiesel

## II. MATERIALS & METHODS

### A.Cottonseed Oil Methyl Ester, COME

COME is extracted in the following method, which consists of three sub-processes such as oil-The extraction of COME is carried out using a method that involves three sub-processes: oil-extraction, esterification, and transesterification. The steps involved in oil-extraction were carefully considered as follows. The cotton seeds were dried to eliminate moisture, and the oil was extracted through seed crushers. The raw oil undergoes filtration multiple times to eliminate any solid impurities. The raw oil is heated to 120oC for a duration of 30 minutes. The preheating process has the advantage of eliminating the saponification reaction [32]. Understanding the role of free fatty acids and moisture in biodiesel production is crucial, as their presence can impact the yield. When alkali catalysts come into contact with free fatty acids, they form soap, which ultimately leads to a decrease in the biodiesel yield. Using high-quality sulfuric acid (99% pure, Merc), the esterification process is carried out to ensure that the FFA content in the original oil remains below 0.6%. In the process of esterification, a mixture of sulphuric acid and methanol is added to the raw oil in specific proportions. The mixture is then heated under steady-state conditions. After the esterified bath is prepared, the transesterification process takes place upon cooling. During this process, methanol (in a molar ratio of 1:8) and KOH (in a volume-to-volume ratio of 1%) are introduced to the bath. The heating conditions used are identical to those employed in the previous reaction. Thus, JOME is obtained, and it has a greenish-yellow color. The properties can be found in table 1, and equation 1 illustrates the transesterification process.

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

**Table 1. Physical and Chemical Properties of Base Fuels**

| | Diesel | BB1 | BB2 | BB3 | BB4 | BB5 | BB6 |
|---|---|---|---|---|---|---|---|
| Density ($Kg/m^3$) | 829.5 | 831.7 | 827.5 | 825.2 | 830.3 | 824.8 | 824.3 |
| K.V at $40^0C$(Cst) | 2.9 | 3.38 | 3.37 | 3.356 | 3.23 | 3.22 | 3.20 |
| CV (MJ/kg) | 44.32 | 43.4 | 43.4 | 43.465 | 43.5 | 43.5 | 43.5 |
| CN | 54 | 52.5 | 53.3 | 54.6 | 52.4 | 53.1 | 53.7 |
| Oxidation stability (hrs) | 59 | 33 | 34.5 | 35.3 | 34 | 36.2 | 37.6 |

**2.1 Pilot Fuel Preparation and their Properties**: 2.1 Introduction to pilot fuel preparation and its properties: For this experiment, a certain amount of n-Octanol (5%) is mixed with a solution containing 20% COME and 75% petrodiesel, using an agitator. The mixture is thoroughly stirred for one hour and given the designation BB1. Using a physical chemistry approach, the nano GO (25 mg/litre on mass basis) is carefully dispersed in BB1 and subjected to ultrasonication for approximately two hours until a uniform mixture is achieved. The mixture is poured into the agitator for an additional two hours to enhance the stability of the pilot fuel, resulting in the creation of BB2. In a similar manner, additional pilot fuels are created using the designated amounts of base fuels and additives. Ensuring the stability of the pilot fuels becomes a crucial concern in the presence of nanoparticles. Using the direct sedimentation approach, the stability of the nano-fuels is tested in the present study. After closely monitoring all nano-fuels for over a week, we found no signs of sediment particles or phase separation. Here are the different pilot fuels that were examined in this study.

BB1: 20% JOME + 5% n-Octanol+75% Petrodiesel

BB2: 20% JOME + 5% n-Octanol+ 25 ppm GO +75% diesel


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BB3: 20% JOME + 5% n-Octanol+ 50 ppm GO +75% diesel

BB4: 20% JOME + 10% n-Octanol +70% diesel

BB5: 20% JOME + 5% n-Octanol+ 25 ppm GO +75% diesel

BB6: 20% JOME + 10% n-Octanol+ 50 ppm GO +75%diesel

### B. Experimentation:

The sequential testing is illustrated as follows. Firstly, the test rig is warmed up for approximately 10 minutes using traditional petrodiesel fuel. Following that, the fuel line is then switched to the pilot fuel. The load on the engine is adjusted by manipulating the load sensing valve. Finally, the data is collected from different devices when they are in a stable state. In this study, the consistent exhaust gas temperature (± 1°C) highlights the importance of maintaining a steady-state condition. The aforementioned steps are repeated with all test fuels under varying load conditions. Following the completion of tests using a pilot fuel, the fuel line is then switched to petrodiesel. The test engine is then allowed to run under no-load conditions for ten minutes. This helps to clean the injection system and prevent thermal cracking. An analysis is conducted on the performance attributes and emission profiles of the test engine, utilizing various pilot fuels. Figure 1 provides the layout of the experimental test engine, while Table 2 showcases the specifications that were demonstrated

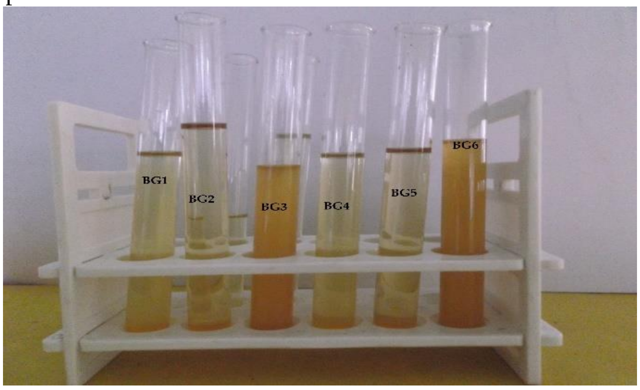


**Fig 1: Test samples**

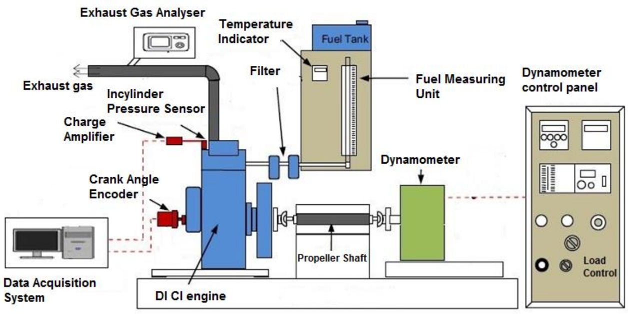


**Fig 2. Schematic Diagram of Engine setup**

**Table II. Test Rig Specifications [1]**

| Sl. | Engine Components | Specifications |
|---|---|---|
| 1 | Make | Kirloskar |
| 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 o/p |
| 18 | Lub.Oil Sump Capacity | 3.7 Lt |
| 19 | Injection pressure | 205 bar |

### C. Uncertainty Study:

Flue gas analyzers, flow meters, and loading equipment were among the several instrumental rigs used in the experiment, and their use was closely tied to the experimental uncertainty condition. Table 5 shows a variety of instruments used for measuring different entities and their uncertainties. These equipment include things like crank angle encoders, eddy current dynamometers, and other flow measurement devices. Equation 2 below shows the results of the mathematical calculation of the total percentage uncertainty δX in the present investigation, which applied RMS approach [32].

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

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

$$= 1.407$$

## III. RESULTS AND DISCUSSION

### A. BSEC

The amount of energy required to produce a unit of power is referred to as brake specific energy consumption, BSEC.

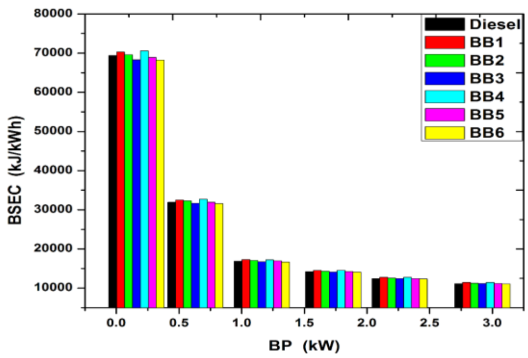


**Fig 3: BP Vs BSEC**

This parameter is highly valuable when comparing fuels with varying heating values. The parameter depends on the amount of charge injected into the cylinder and the heating value [34].

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The BSEC of the engine increases at minimum BP, but as the engine BP increases, the BSEC of the engine shows a decreasing trend. At full load condition, BB6 engine achieved a lower BSEC of 11040 kJ/kWh, which is 1.26% lower than the base fuel, pure diesel. The other sample BB3 was 0.48% lower than the base fuel diesel. The decrease in consumption can be attributed to the enhanced energy densities of the biodiesel blends, which are achieved through the incorporation of an ignition improver. The catalytic action of the graphene was found to be more efficient compared to the other alcohols that were tested [1] [32].

### B. Brake Thermal Efficiency (BTh)

The Brake thermal efficiency (BTh) in comparison with engine Brake Power for different blends is illustrated in Figure 5.3. The BTh of a compression ignition diesel engine is influenced by factors such as the fuel-air ratio, compression ratio, fuel properties, and fuel combustion. The increase in engine BTh is quite significant compared to the engine BP. When the engine is operating at higher loads, the increased fuel supply leads to the accumulation of fuel inside the cylinder, causing a decrease in the slopes of the curves. [35]. The highest BTh of 34.65% was achieved in the BB3 blend, which is 3.28% higher than that of diesel. This increase in heating value can be attributed to the use of biodiesel-diesel-alcohol mixes. The following blend, which achieved a higher BTh, is BB6. It is 2.29% higher than diesel and 2.9% lower than BB3 in comparison. This outcome was achieved due to the elevated oxygen content in the biodiesel, the presence of an additive, and the enhanced catalytic properties of graphene, resulting in a thorough combustion process [1].

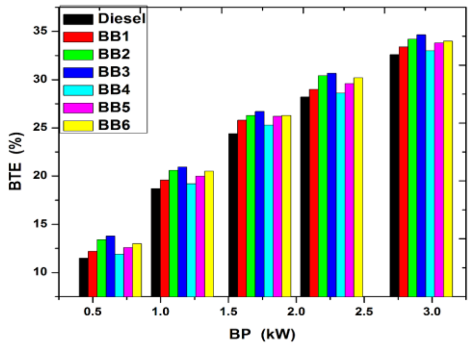


**Fig 4: BP Vs BTE**

### C. Carbon Monoxide CO

The figure illustrates the correlation between carbon monoxide levels and BP for various fuel blends. It was discovered that higher engine brake power values lead to increased CO emissions due to a greater amount of charge induction, resulting in a shorter time for complete combustion. Based on the graph, it is evident that the recorded CO values for all the test fuels were lower than that of the base fuel diesel. With the presence of higher alcohols and biodiesel, the oxidation phenomenon of CO is enhanced due to the increased oxygen content. However, the fuel samples treated with nanographene exhibited a small rise in CO emission [35]. This is due to the decrease in CO oxidation. The catalytic action resulted in a decrease in ignition delay and an acceleration in combustion, leading to a slightly higher CO emission compared to blends treated solely with higher alcohol. The biodiesel blend BB4 is generating significantly lower values, with a reduction of 24.65% compared to diesel. Similarly, BB1 is also producing a decrease of 16.3% compared to diesel. With the addition of ignition improver BB2, BB3 is now producing 3.1% more than BB1 and 20% lower than diesel. In comparison, BB4 is generating 26% fewer emissions than diesel. With the inclusion of ignition improver BB5, BB6 is now generating 2, 3.48% higher output compared to BB4, while still maintaining a 20.1% lower efficiency than diesel [32].

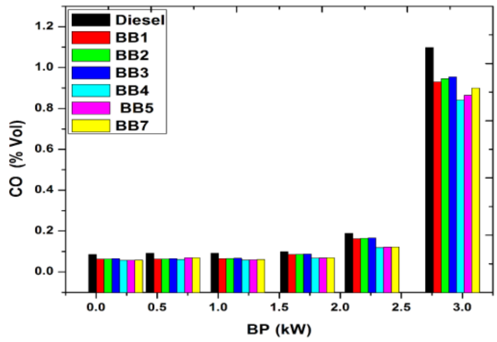


**Fig 5: BP Vs CO**

### D. Unburnt Hydro Carbon (HC.u)

The figure illustrates the relationship between carbon monoxide levels and BP for various fuel blends. At higher engine brake power values, the unburnt hydrocarbon emissions are significantly higher in almost all the test samples, including base fuel diesel. The test fuels exhibited a decreasing trend when compared to the base fuel diesel [36]. It is evident from the graph that the use of biodiesels and the addition of higher alcohols as additives have significant potential benefits. The alcoholic biodiesel blend BB1, BB4 exhibited lower HC.u levels (16%, 20%) in comparison to diesel.

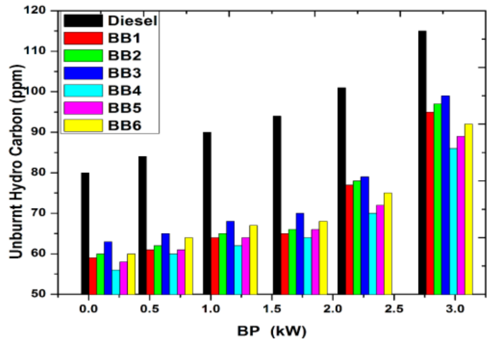


**Fig 6: BP Vs UHC**

On the other hand, the inclusion of an ignition improver led to a slight increase in Unburnt Hydro Carbons due to the slower oxidation of CO caused by the improved diffusion combustion.

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BB2 and BB3 demonstrated a reduction of 15% and 11% in emissions, respectively, while BB5 and BB6 showcased a decrease of 17.5% and 15% when compared to the base fuel diesel. BB2 and BB3 exhibited a 1.7% and 6.8% increase in emissions, respectively, compared to BB1. Similarly, BB5 and BB6 experienced a 3.6% and 7.1% increment in emissions, respectively, when compared to BB4. By incorporating nanographene, the air-fuel blending process is enhanced, leading to a reduction in pre-mixed combustion time. This, in turn, extends the diffusion combustion phase and results in a slight increase in HC.u values [1].

### E. NOx Emissions

The NOx emissions depend on the cetane index of the fuel sample. Using fuel with a higher cetane index can help decrease ignition delay, resulting in lower NOx emissions [33]. While using oxygenated biodiesel blends typically leads to increased NOx emissions, the introduction of n-Octanol had the opposite effect by cooling the combustion chamber and reducing NOx levels. However, based on the graph, it appears that the alcohol treated fuel samples resulted in higher NOx values, indicating a functional drawback. The graph clearly shows the potential benefits of using an ignition promoter such as nanographene. The higher cetane index of the samples was significantly boosted. With the use of fuels that have a higher cetane index, the combustion process is enhanced, resulting in earlier ignition and increased pressure and temperature. This ultimately helps to reduce NOx emissions. The engine brake power [37] shows an increasing trend for all fuel samples, including diesel. When compared with the baseline fuel diesel, the higher alcoholic biodiesel samples BB1 and BB4 are only producing 2.07% and 3.1% more NOx. However, the inclusion of nano graphene resulted in even lower NOx emissions [39]. Specifically, BB2 and BB3 showed a reduction of 1% and 2.1% respectively compared to the baseline fuel. Similarly, BB5 and BB6 exhibited a decrease of 0.41% and 1.7% in NOx emissions. The performance of BB3 is quite promising in comparison to diesel. Indeed, the reduced vapor pressure of n-Octanol functions as a cooling agent for the charge, which in turn lowers NOx emissions when combined with nano graphene [32].

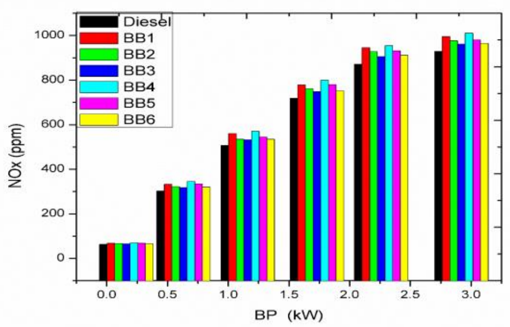


**Fig7: BP Vs NOx**

## IV. CONCLUSION

A study was conducted to examine the emission profiles and performance of petrodiesel, diesel mixtures, and biodiesel on a single cylinder water-cooled CI engine. Here are the findings from this investigation at full load:

At full load, the BB6 engine consumed slightly less fuel compared to pure diesel, with a reduction of 1.26%. The decrease in consumption can be attributed to the enhanced energy densities of the biodiesel blends, which are achieved through the incorporation of an ignition improver. The graphene's catalytic action was more efficient compared to the other higher alcohol treated samples.

The brake thermal efficiency rises as the biodiesel percentage increases. With the BB3 blend, the brake thermal efficiency reached an impressive 34.65%. Surprisingly, this is 3.28% higher than that of diesel. The reason for this increase is the higher heating values of biodiesel-diesel-graphene mixes. The complete combustion of the fuel is attributed to the presence of graphene in the biodiesel.

There were observed reductions in the unburned hydrocarbon emissions in biodiesel blends BB1 and BB4, which showed the smallest reduction in hydrocarbons compared to the other blends when compared to diesel fuel.

A significant decrease of 24.65% in CO emissions is observed in the BB4 when compared to the conventional diesel. An increase of 2.1% in NOx emission is observed in biodiesel BB3 when compared with diesel, while the other blends show a slightly smaller decrease compared to BB3.

## DECLARATION STATEMENT


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|---|---|
| Funding | No, I did not receive. |
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| Ethical Approval and Consent to Participate | No, the article does not require ethical approval and consent to participate with evidence. |
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| Authors Contributions | All authors have equal participation in this article. |


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## AUTHORS PROFILE

**Dr. Kiran Kumar Billa,** an esteemed energy expert, serves as a beacon of knowledge and innovation in the Mechanical Engineering Department at Sasi Institute of Engineering and Technology. With a profound passion for sustainable energy solutions, Dr. Billa epitomizes the blend of academic rigor and practical application. His expertise spans across various facets of energy engineering, including renewable energy systems, energy conservation, and thermal management. Dr. Billa's research endeavors have contributed significantly to the development of novel technologies aimed at mitigating environmental impacts while enhancing energy efficiency. Within the academic sphere, Dr. Billa is renowned for his dynamic teaching methodologies, fostering a stimulating learning environment where students are encouraged to explore, innovate, and engage critically with energy-related challenges. He mentors aspiring engineers, instilling in them a deep understanding of the intricacies of energy systems and inspiring them to become agents of positive change in the field. Beyond academia, Dr. Billa actively collaborates with industry partners, leveraging his expertise to address real-world energy challenges and drive innovation in sustainable engineering practices. His dedication to advancing the frontier of energy engineering makes him a pivotal figure in shaping the future of clean energy technologies. Dr. Kiran Kumar Billa's unwavering commitment to excellence and his relentless pursuit of sustainable solutions make him an invaluable asset to the academic community and the broader field of energy engineering.

**P.H.V.Siva Prasad,** an U.G. student in the department of mechanical engineering department He immerses in the fusion of theoretical knowledge and hands-on exploration. Fueled by curiosity, they dissect complex machinery, deciphering the intricate dance of gears and levers. In lecture halls, they absorb principles of thermodynamics and fluid mechanics, eager to apply them in real-world scenarios. With grease-stained hands and a mind ablaze with innovation, they thrive in workshops, crafting prototypes and refining designs. Their passion extends beyond textbooks, embracing challenges with zeal, driven to engineer solutions that shape the world. With every project, they sculpt their future, embodying the relentless spirit of ingenuity that defines the mechanical engineering discipline. An undergraduate majoring in mechanical engineering,

**M.D.V. Satyasai** becomes engrossed in the combination of academic understanding and practical investigation. Their insatiable need for knowledge drives them to dismantle elaborate machines and figure out how all the moving parts work together. Aspiring to put what they learn in class on fluid mechanics and thermodynamics into practice, they cram for lectures on the subject. Workshops are their happy place as they labor tirelessly to perfect concepts and create prototypes with grease-stained hands and an innovative spirit. Driven to build solutions that impact the world, their enthusiasm transcends beyond textbooks. They embrace difficulties with fervor. They exemplify the indefatigable spirit of innovation that characterizes mechanical engineering with each project they take on, shaping their future.

**K.K.V.V. Krishna Aditya** is also an under graduate student in mechanical engineering. Combining academic understanding with practical investigation is what he becomes engrossed with. They break down complicated machines, piece together the complicated motion of gears and levers, all because they want to know how it works. Students eagerly acquire concepts of fluid mechanics and thermodynamics in classrooms, with the goal of applying them in real-world situations. They excel in workshops, making prototypes and perfecting concepts with grease-stained hands and an innovative mind. Beyond what they learn in the classroom, they are enthusiastic problem solvers who are compelled to make a difference in the world via their engineering. Their future is shaped with each project, exemplifying the indefatigable spirit of innovation that characterizes mechanical engineering.

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