Influence of Metal Based Nano Fuels on the Engine Performance and Emissions

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Abstract:
In the ongoing experiment, the emissions and performance specifications of the 4-stroke water cooled diesel engine using biodiesel pongamia pinnata with and without graphene additives are assessed. The use of nanoparticles may be beneficial for biodiesel in engine operation. Nanoparticle suspension in biodiesel can be successfully achieved using solvents that provide a strong bond between biodiesel and nanoparticles to overcome differences in density. Surfactants can be used when mixing liquid with nanoparticles to prevent the sinking or floating of nanoparticles in biodiesel. The use of nanoparticles increases the combustion mechanism due to its rapid combustion and thus decreases emissions as well. The tests for emission levels and performance were carried out at 1500 revolutions per minute constant engine speed. The results of experimentation shows that the addition of graphene to the blends of biodiesel, the curve of brake thermal efficiency (BTE) shifted on the higher side and almost very close to the diesel. The improvement in BTE is found to be 1 to 1.5%.
Keywords: Biodiesel; Pongamia pinnata; Graphene; Diesel engine; Performance; Emission.
Fuel blends description:
B10- 10% Pongamia Biodiesel and 90% diesel
B20- 20% Pongamia Biodiesel and 80% diesel
B30- 30% Pongamia Biodiesel and 70% diesel
B10Gr100- 10% Pongamia Biodiesel, 90% diesel and 30 PPM Graphene
B20Gr100- 20% Pongamia Biodiesel, 80% diesel and 30 PPM Graphene
B30Gr100- 30% Pongamia Biodiesel, 70% diesel and 30 PPM Graphene
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1. Introduction

For any country meeting their energy demands is the greatest challenge in the modern era that determines the country's Gross domestic product (GDP). Most developing countries rely on imported fossil fuels to meet the enormous demand for fuel, both for transportation and for power generation. Consequently, the sharp increase in oil prices is seen everywhere. The net importation of crude oil into India accounts for 80% of total fuel requirements, representing 30% of India's foreign exchange revenues. India's crude oil import bill jumped 76 % in the first half of 2022-23, while total imports rose 15 per cent to 116.6 million tons. India still occupies fourth place in the consumption of petroleum products in the world today. It is therefore crucial to develop appropriate long-term tactics based on renewable fuel consumption that would phase out diesel imports and reduces emissions [1]. Biodiesels will therefore be considered an improved substitute for diesel fuel [10-14]. The inclusion of graphene particles leads to a substantial reduction in burning time and increase in maximum cylinder pressure bit. Many researchers have experimented with blending biodiesels with graphene at various proportions to power diesel engines. It has been observed that this mixture improves physical and chemical properties [2, 12, and 13].

B. M. Paramashivaiah et al [2] used simaruba bio diesel mixed with Nano particles to evaluate the CI engine performance. The results obtained shows optimum performance for 20% blend with 40PPM of graphine nano particles. The engine showed a better performance with the blend. Further, there was an improvement in BTE and reduction in HC, CO and NOx[9, 10, 11,14, 15, 16,17, 18 and 19].

S.R. Arote et al [3] reported by conducting extensive literature survey the pongamia Pinnata is a milestone in the field of Bio fuel. However, it is noticed that evaluation must be performed on the pongamia pinnata to i explore obscure areas and their useful applications, which can be employed for the well-being of humanity.

Vigya Kesari et al [4] has published a paper on literature review to examine the issues involved in pongamia pinnata plantation, a number of elements of the utilization of premium planting material and suitable breeding methods, including nursery and planting practices.

G.R. Kannan et al [5] had investigated how metal-based Nano additives affected diesel engine performance, emissions, and combustion characteristics. It was shown that there is slight improvement in BSFC, BSEC and BTE by the use of fuel based catalyst. Additionally, it was noted that CO and UHC levels were decreased, while NOx and CO2 levels had slightly increased. The author further notes that under ideal operating circumstances, the fuel-based catalyst added to biodiesel demonstrated a higher gas pressure, higher heat release rate, and shorter igniting delay.

M. Prabhahar et al [6] here studies are conducted for vegetable oil methyl ester and compared with neat diesel fuel. It yields to following conclusions. The peak pressure and release rate of heat shows less values whereas ignition delay decreases for biodiesel blends at the same time it can be notices there is increasing combustion duration.

In this experiment, graphene based nanobiodiesel was prepared by scattering graphene in a mixture of pongamia pinnata and diesel. A single-cylinder-four stroke computerized diesel engine was used for the emissions and performance testing of graphene nano-biodiesels. The readings are tabulated for three bio diesel blends with and without graphene nanoparticle addition. The effects of graphene nano-biodiesel result in a 1.5% improvement in brake thermal efficiency, reduction of 31.2 percent in carbon monoxide (CO), unburnt hydrocarbon (HC) by 12.3%, and emissions of oxides of nitrogen (NOx) reduced by 3% with in comparison with biodiesel blends without graphene. Also the addition of graphene particles has led to marginal reduction in duration of combustion and a cylinder peak pressure is somewhat raised under all loading scenarios.

2. Materials used and methodology

2.1 Graphene

Graphene is a one-ply carbon atom, bound together in a honeycomb structure. It is the thinnest material uncovered ever having 0.335 nm inter-planar distance. It got large specific area of 2629 m2/g and the heat conductivity value of 5000 W/m-K at room temperature. 350 degrees Celsius is just the low temperature at which graphene burns. Table 1 provides a list of the used graphene's properties.

Table 1: Properties of grapheme

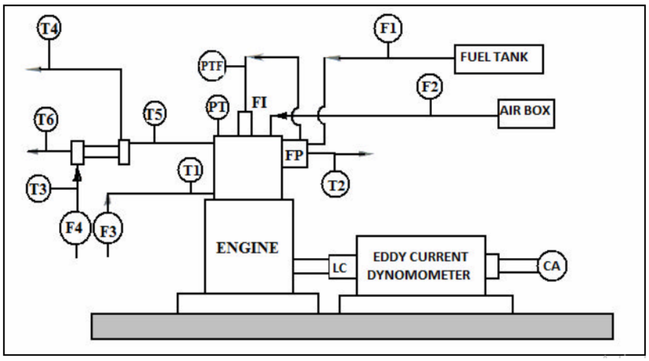
Sl. No.	Parameter	Property
1	Average particle size	22.5–26 nm
2	Surface area	492 m^2/gm
3	Purity	99.5%
4	Thermal conductivity	3000 W/m-K

2.2 Biodiesel Used

The biodiesel used to do this work was pongamia pinnata. pongamia pinnata is a legume known for its many benefits and as a feasible fount for growing biodiesel. It got advantage of growing on dry land make it an appropriate candidate in agroforestry. These properties support the plant's ability to produce on a large scale in a sustainable biodiesel industry. Initially, characteristics of the test engines' combustion and emissions are studied with normal diesel fuel under different loads at standard operating conditions, such as 20%, 40%, 60% and 80% loads. During the second phase of the work, biodiesel mixtures B10, B20 and B30 were prepared by mixing pongamia pinnata with diesel. In the third phase of the work, mixtures of graphene nano-biodiesel B10Gr, B20Gr and B30Gr were prepared by blending nanoparticles of pongamia pinnata, diesel and graphene. Later tests were conducted using the fuels prepared to obtain the engine performance and emission readings. Graphs are plotted for average values of three readings. Finally, results such as BSFC, BTE, and emissions such as HC, CO and NOx were compared to the reference data and analyzed.

3. Experimental setup

Engine configuration diagram used to evaluate efficiency, combustion and emission characteristics. of biodiesel pongamia pinnata with and without graphene additives in normal operational conditions is shown in Fig. 1. Table 2 describes the technical specifications for the engine configuration. Engine speed and torque are automatically monitored by an eddy current dynamometer. AVL DiTEST gas analyzer was used appropriately to determine regulated emission levels, such as HC, CO and NOx that use non-dispersive infrared technology. The gas analyzer were first calibrated before testing commenced. The pressure variation in the cylinder was achieved using a pressure sensor located on the motor cylinder head. The properties of the test fuels are presented in Table 3 and 4.



PT-Combustion Chamber Pressure Sensor T1-Jacket Water Inlet Temperature T2-Jacket Water Outlet Temperature
T3- Inlet Water Temperature at Calorimeter T4- Outlet Water Temperature at Calorimeter
T5- Exhaust Gas Temperature before Calorimeter T6- Exhaust Gas Temperature after Calorimeter
FI- Fuel Injector F1-Liquid fuel flow rate F2- Air Flow Rate F3-Jacket water flow rate
F4-Calorimeter water flow rate EGC-Exhaust Gas Calorimeter LC-Load Cell CA-Crank Angle Encoder

Fig. 1: Experimental Setup Line Diagram

Table 2: Diesel Engine and Dynamometer Specifications

Parameter	Specifications
Make & Model	Kirloskar-TV1
Injection pressure	190 bar
Rated power	3.5 kW @1500rpm
No. of cylinders	Single cylinder
Compression ratio	16:01
Bore diameter	87.5mm
Stroke length	110 mm
Dynamometer	Eddy Current Dynamometer

Table 3: Physical and chemical properties of Diesel and Biodiesel blends

Property	Diesel	B10	B20	B30
Density (kg/m^3)	830	840.4	844.8	849.2
Viscosity (Cst)	3.46	4.18	5.59	6.82
Calorific value (MJ/kg)	44.66	42.98	42.46	42.13
Flash Point (°C)	50	66	76	85
Ash content (% w/s)	0.01	0.015	0.021	0.026

4. Results and discussion

Experimental investigations were conducted on pongamia pinnata biodiesel blends of B10, B20, B30, B10Gr, B20Gr and B30Gr. In order to assess how well an engine performs on diesel and various blends of biodiesel, constant speed C.I engine undertook fuel consumption measurements as well as rating tests. The variation of BSFC versus Brake power is shown in figure 2. The BSFC for the diesel is highest and for the blend B10 biodiesel with 30ppm graphine is lowest. As it is well know the oxygen content in the bio fuels is more that leads to better and complete combustion and addition of nano material leads to compensate for lower calorific value of the bio fuels [7], the blend of bio diesel with Nano materials has lower BSFC.

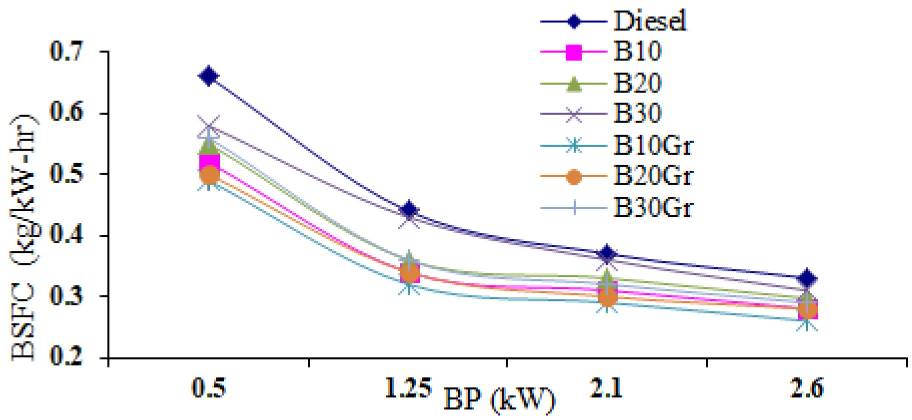


Fig. 2: BSFC v/s BP

The fluctuation of BTE with load is seen in Figure 3. The BTE for diesel seems to be on higher side and that for diesel with bio diesel blends is on lower side as the Calorific value is lower for bio diesel blends. Further when we add the graphine to the blends the curves shifts on the higher side and almost very near to diesel between 28% - 30% and for 80% loading. The improvement in BTE is found to be 1 to 1.5%

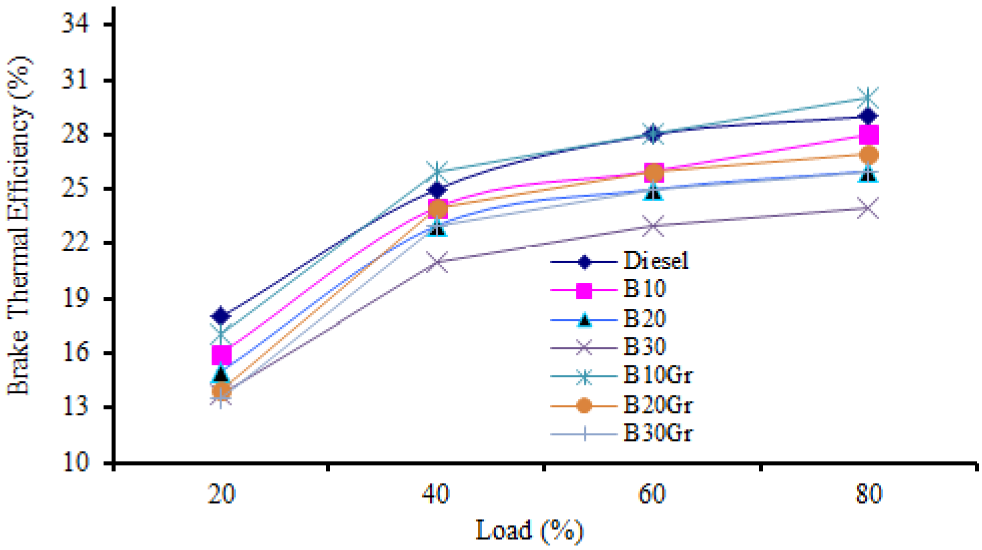


Fig. 3: BTE v/s Load

The figure 4 indicates the variations of in cylinder peak pressure v/s load. The pressure for neat diesel is in the middle range. We know the calorific value for bio diesel is less than diesel hence the curves of B10, B20 and B30 are on the lower side. Further the blends after mixing with 30ppm of graphine shown the improvement in peak cylinder pressure as the nano particles added gives fuel characteristics help to improve CV and hence peak pressure are more diesel by 2 to 3 bars.

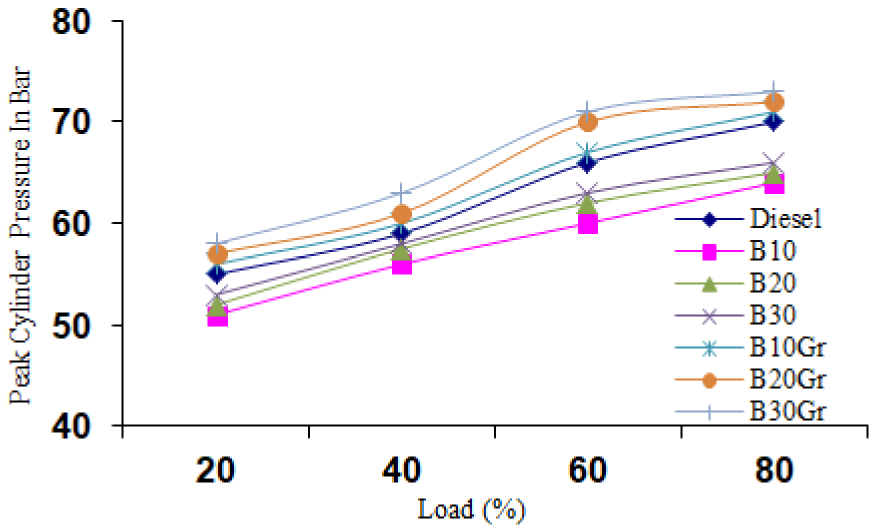


Fig. 4: Peak Pressure v/s Load

The delay period is found to decrease with bio diesel and with addition of nano particles again come back nearer to diesel which is depicted in the figure 5. The variation in delay period is not very much significant and the variation is within 2 degrees of crank angle.

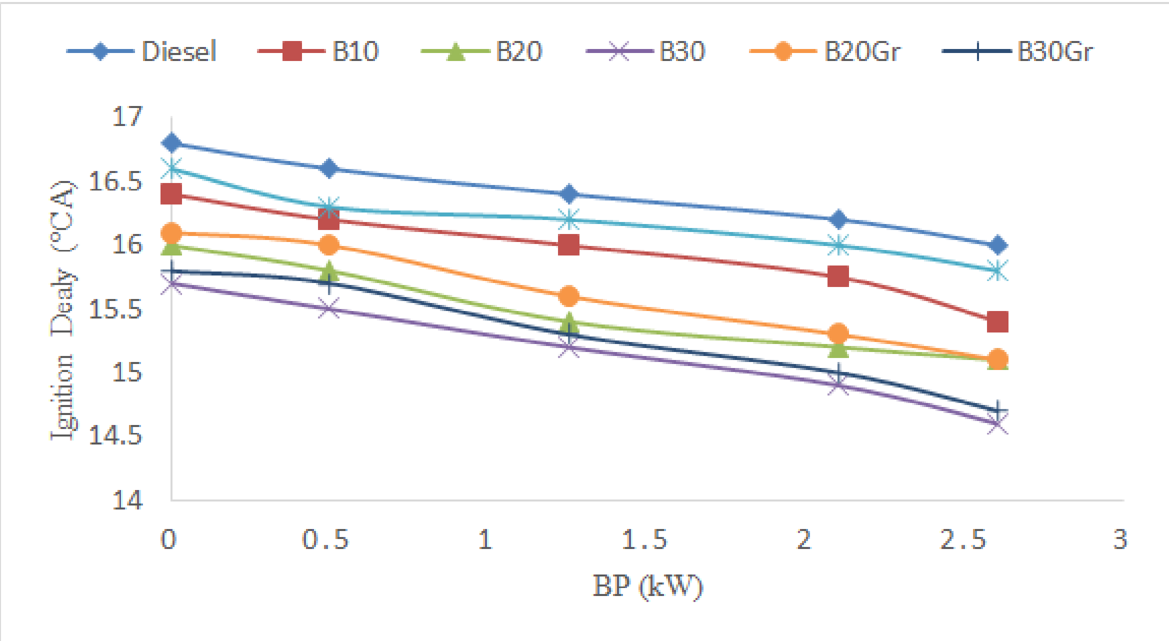


Fig. 5: Ignition Delay v/s BP

The combustion duration V/S BP is indicated in figure 6. The combustion duration is around 33 to 35 degree CA for bio diesel and is found to decrease to 27 to 30 degree CA for diesel. With the addition of nano material the combustion duration again comes back nearer to diesel as nano materials adds to combustion improvements, where as in case of bio diesel blends the small increase in viscosity leads higher evaporation time during initial phase of combustion.

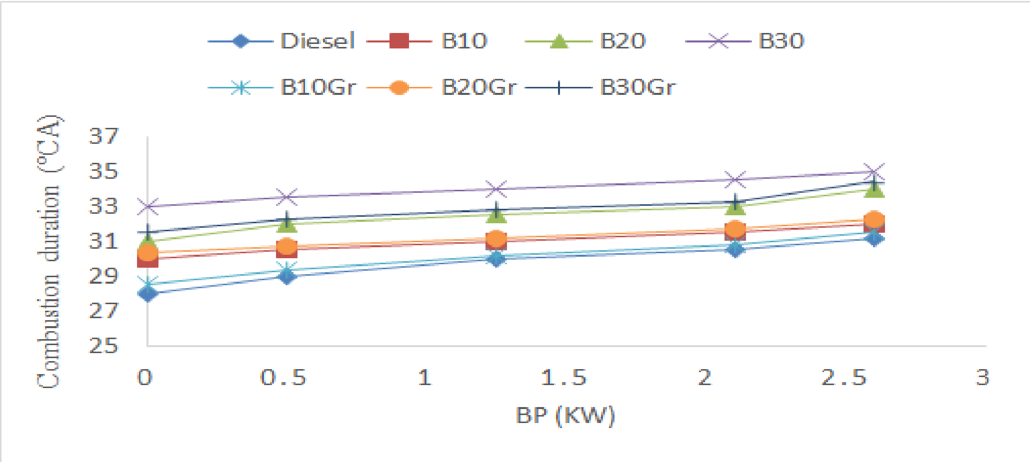


Fig. 6: Combustion Duration v/s BP

The changes in CO emission with BP are shown in figure 7. The emission of CO is found to decrease for bio diesel and further lowered with the addition of Nano particles of graphene. The reason behind the lowered CO emissions are the excess oxygen content in bio fuel which has led to improving in combustion towards complete combustion, higher peak pressure and temperature also helps in reduced CO emissions.

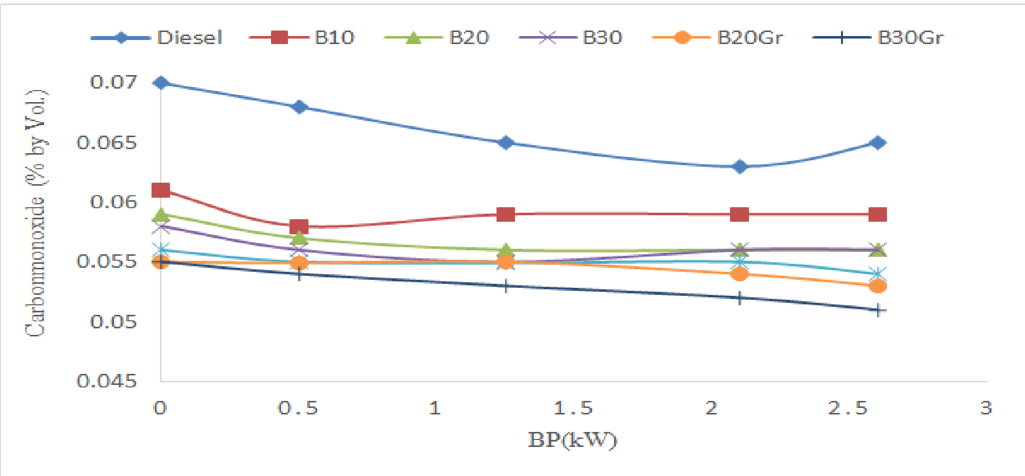


Fig. 7: CO Emission v/s BP

The figure 8 shows the UBHC V/S BP. The result indicate that the UBHC has shown a decreasing trend for bio diesel and further decreases for addition of nano materials to the bio diesel blends[8]. The reasons quoted for CO emissions also holds good for justification in reduced UBHC. At the same time we can see an increased NOx as CO and UBHC decreased which will be further investigated. The decrease in CO and UBHC are very marginal from 5 to 6%

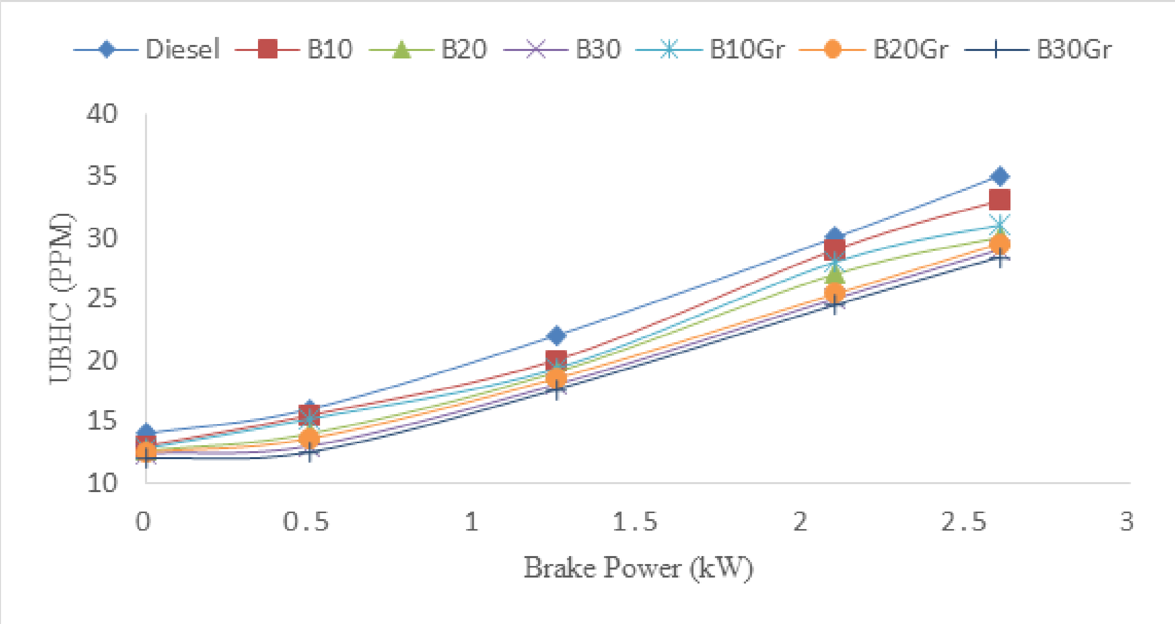


Fig. 8: UBHC Emission v/s BP

5. Conclusion

Conclusions from research on a single-cylinder diesel engine on pongamia pinnata-infused diesel fuel with and without graphene nano particles were compared to those of a baseline engine for performance, combustion, and emissions. When compared to diesel fuel, smooth engine functioning has been seen with graphene added fuel. Additionally, the BTE curves change higher and practically extremely close to diesel between 28% and 30% for 80% loading when the graphine is added to the blends. BTE has been shown to have improved by 1% to 1.5%. The BSFC for the diesel is highest and for the blend B10 biodiesel with 30ppm graphine is lowest. Biodiesel with graphene added is determined to have a minimum CO emission reduction of 20% when compared to diesel. The least amount of HC emissions for biodiesel as compared to diesel is reported to be 12 ppm for B30Gr blend.

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