Performance and Emission Characteristics of Graphene Nano Particle-Biodiesel Blends Fuelled Diesel Engine

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Abstract - *Experimental investigations were carried out to determine performance and emission characteristics of diesel engine using graphene nanoparticles blended biodiesel fuels. The fuel combinations used for the study were neat diesel and graphene nanoparticle blended biodiesel. The biodiesel was prepared from Waste Cooking Oil Methyl Ester (WCOME). The graphene nanoparticles were blended with the biodiesel fuel in the mass fractions of 20ppm, 40ppm and 60ppm with the aid of an ultrasonicator. Subsequently, the stability characteristics of graphene blended biodiesel fuels were analysed under static conditions.*

The investigation were carried out using an experimental set-up consisting of a single-cylinder four stroke diesel engine coupled with an eddy current dynamometer loading device and the results shown that improvement in the calorific value, reduction in flash point , higher enhancement in the brake thermal efficiency and reduction in the harmful pollutants for the blend of graphene nanoparticle due to the incorporation of graphene nanoparticle gives more surface area for reactivity and having higher thermal conductivity were observed.

***Key Words*: Graphene Nanoparticles, Properties, Diesel Engine, WCOME, Biodiesel, Graphene Nanoparticle-Biodiesel Blends, Ultrasonicator, and Emission.**

1. INTRODUCTION

Now a days, the rapid growth in industrialization has made the transportation sector of a magnificent importance. This transportation sector is dependent upon availability of fossil fuel i.e. Petrol and diesel and require it in abundant for its sustainability. Hence there is ever growing need of the fossil fuel and it need to be satisfied. But due to their limited resources and increased demands has made the costs of these fuels increase continuously. Apart from these higher costs, this fossil fuelled vehicles has led to increase in the pollutants such as CO, NOx, lead, soot, and degrades the environment. In this context, biodiesel has seemed as one of the most potential renewable energy to replace present commercial diesel. Also, it is easily available, biodegradable and harmless fuel which can be easily produced through transesterification reaction in presence of catalyst. However, such biodiesel based fuel cannot directly use in diesel engine due to high ignition delay, low cetane number, high brake specific fuel consumption, low calorific value, and low brake thermal efficiency. Biodiesel can be used with diesel fuel at different proportions, as it has very similar characteristics but lower exhaust emissions. Biodiesel fuel has healthier properties than those of diesel fuel such as renewable, eco-friendly, nontoxic, and basically free of sulphur. The burning of fossil fuels is connected with emissions such as CO_2, CO, NO_x, SO_x, and particulate matter, which are presently the foremost global sources of emissions. With the use of biodiesel in diesel engines can reduce carbon oxides, carbon monoxide, hydrocarbon, and particulate matter emissions, but nitrogen oxide emission may increase.

The performance characteristics of engine with biodiesels are little less compared to the base fuel diesel. Many researchers are experimentally investigated by adding additives like metal and metal oxides nanoparticles, liquids (methanol, ethanol) to the biodiesels. Recent understanding and advance in materials science have led to exciting potentials in the development of propulsion fuels. These consist of nano particles, nanotubes, graphene, and reactive nanocomposite powders. In this view the nanoparticles are added to base fuel due to their most remarkable properties like thermal properties, mechanical properties, specific surface area, magnetic, electric properties, optical properties, reactivity, high surface to volume ratios and energy densities. Graphene has attracted much attention from researchers by virtue of its interesting mechanical, electrochemical and electronic properties. Graphene, a single atomic layer of sp2-bonded carbon atoms tightly packed in a two dimensional (2D) honeycomb lattice, has evoked great interest throughout the scientific community since its discovery. As a novel nanomaterial, graphene possesses unique electronic, optical, thermal, and mechanical properties [1].

The nanoparticles can function as a potential catalyst and an energy carrier. Nanoparticles usually measure from 1 to 100 nm in diameter. As the size of the particle changes the property of the material may also change.

2. PREPARATION OF FUEL BLEND

The graphene nano particles will be weighed by using electronic balance. Then nanoparticles are weighed separately for quantities 20mg, 40mg and 60mg accurately. The nanoparticles blended waste cooking oil biodiesel fuel is prepared by mixing the waste cooking oil biodiesel and graphene nanoparticles with the aid of an ultrasonicator. The ultrasonicator technique is the best suited method to disperse the graphene nanoparticles in a fluid, as it facilitates possible agglomerate nanoparticles back to nanometre range. The nanoparticles are weighed to a predefined mass fraction say 20ppm and dispersed in the waste cooking oil biodiesel fuel the blend that prepared is called WCOME+20ppm. The same procedure is carried out for the mass fraction of 40ppm (WCOME+40ppm) and 60ppm (WCOME+60ppm) to prepare the graphene nanoparticles blended waste cooking oil biodiesel fuel.

Figure 1: Nanobiodiesel Blend Preparation, Ultrasonicator

- Weigh the amount of GRAPHENE (20ppm) and add 4ml of methanol and keep it for bath sonicator for 15 minutes.
- Weigh 1:3 amount of sodium dodecyl sulphate (SDS) and add the 4ml of distilled water to dissolve it.
- Mix the dissolved SDS solution with GRAPHENE to wet the nanoparticles.
- Take 500ml of biodiesel and mix with dissolved SDS+GRAPHENE solution and keep it for ultrasonicator for 7minutes.
- Now the nano biodiesel blend is ready for stability analysis.
- Repeat procedure for 40ppm, 60ppm.

The samples of graphene nanoparticles blended waste cooking oil biodiesel fuels are kept in bottles under static conditions for analysing the stability characters. After the preparation of nanoparticle biodiesel blends properties like density, kinematic viscosity and calorific value of prepared blend were determined by using ASTM standard apparatus.

Table -1

Properties of Biodiesel and Nano Biodiesel Blends

Type of fuel	Kinematic Viscosity, cSt @ 40 (°C)	Calorific Value, (kJ/kg)	Density kg/m^3
Diesel	3	43000	840.0
WCOME	4.8	39036.05	847.14
WCOME+20pm	5.1	39618.72	867.14
WCOME+40pm	5.5	39795.37	877.14
WCOME+60pm	5.9	39990.29	891.24

3. EXPERIMENTAL SET-UP

The engine experiments were conducted on 4-stroke single cylinder water cooled compression ignition engine with a compression ratio of 17.5:1, developing 5.2 kW at 1500 rpm. The engine specifications are given in table 2. The engine was operated at a rated speed of 1500 rpm. The injector opening pressure and static injection timing as specified by the manufacturer was 205 bar and 23^0 BTDC respectively. The speed of the engine can be controlled with the aid of governor. The engine was provided with a hemispherical combustion chamber with overhead valves operated through push rods.

Cooling of engine was accomplished by circulating water through the jackets on the engine block and cylinder head. The head of the cylinder is provided with piezoelectric pressure transducer to measure the cylinder pressure. The exhaust gas analyser and smoke meter are used to measure HC, CO, NO_x and smoke opacity.

Figure 2: Pictorial View of 4 Stroke Engine

Table -2

Engine Specifications		
Sl. No	Parameters	Specifications
1	Type	TV1(Kirlosker made)
2	Nozzle opening pressure	200-225 bar
3	Rated power	5.2 kw (7HP) at 1500 rpm
4	Bore	87.5 mm
5	Stroke length	110 mm
6	Compression ratio	17.5:1

4. RESULTS AND DISCUSSIONS

The operation of the engine was to be very smooth throughout the rated load, without any operational problems for the graphene nanoparticles blended biodiesel fuel. The performance attributes such as brake thermal efficiency, specific fuel consumption and the emission characteristics such as NO*x*, CO, HC and smoke density are plotted against brake power.

Engine Performance

4.1 Brake Specific Fuel Consumption

The variation of brake specific fuel consumption (BSFC) with brake power (BP) for diesel, WCOME and nano blends are shown in figure 4.1. The BSFC decreases with increase in BP for WCOME and nano blende fuels at all loads. The BSFC is higher for neat WCOME than other proportions of WCOME-GRAPHENE nano blends. This is due to lower calorific value of WCOME. The BSFC is lowest for WCOME+60ppm nano blend. This might be probably attributed in the presence of GRAPHENE nanoparticles in the blends. It increases the calorific value and density. And also blends possess an improved surface to volume ratio to better catalytic effect and less fuel is consumed per unit volume of the fuel during combustion process.

There is a reduction in BSFC of 2.46% for (WCOME+20ppm), 3.88% for (WCOME+40ppm) and 5.37% for (WCOME+60ppm) blended fuel as compared to WCOME at full load was observed.

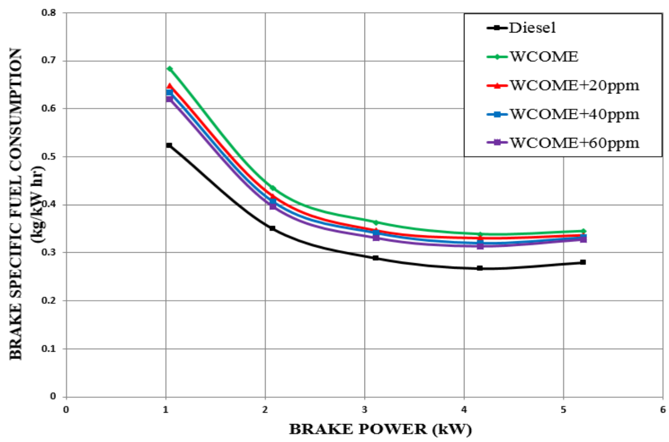

Figure 4.1: BP vs BSFC

4.2 Brake Thermal Efficiency

Figure 4.2 shows variation of brake thermal efficiency for Diesel, WCOME and WCOME-GRAPHENE blended fuels. The brake thermal efficiency for WCOME operation is lower compare to neat diesel. Due to its lower volatility, higher viscosity and lower calorific value. The brake thermal efficiency of the WCOME-GRAPHENE blended fuels is improved compared to neat WCOME operation. This is mainly due to improved combustion characteristics of WCOME-GRAPHENE.

In general, the nanosized particles acts as a potential catalyst that contribute to higher chemical activity Furthermore, in case of WCOME+60ppm fuel, the catalytic activity may improve due to the high dosage of compared to that of WCOME+20ppm. Due to this effect, the brake thermal efficiency is higher for WCOME+60ppm compared to that of WCOME+20ppm [1]. There is an increase in BTE of 1% for (WCOME+20ppm), 1.86% for (WCOME+40ppm) and 2.84% for (WCOME+60ppm) blended fuel as compared to WCOME at full load was observed.

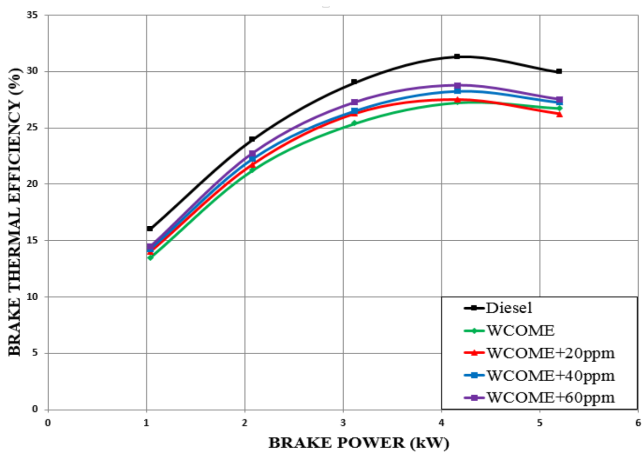

Figure 4.2: variation of BP vs BTE

4.3 Volumetric Efficiency

The variation of volumetric efficiency with brake power is shown in figure 4.3. Volumetric efficiency decrease as the load increases. Volumetric efficiency for diesel operation is higher compare to neat WCOME. It is obvious to decrease since mass of air which enters the cylinder decrease with decrease in concentration of the GRAPHENE nanoparticles in the biodiesel. Also the air which is inducted into the cylinder has lower density hence requires more mass to occupy the volume of the cylinder which significantly decreases the breathing capacity of the engine. There is an increase in volumetric efficiency of 1% for (WCOME+20ppm), 4.45% for (WCOME+40ppm) and 5.3% for (WCOME+60ppm) blended fuel as compared to WCOME at full load was observed.

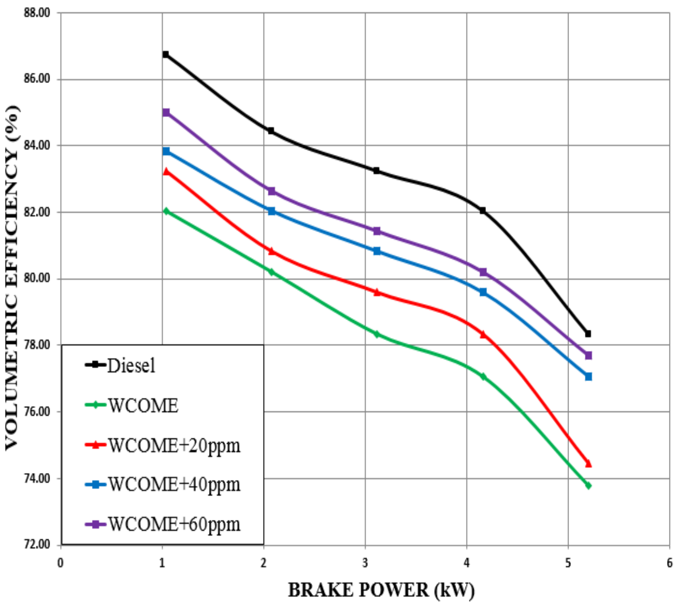

Figure 4.3: BP vs Volumetric Efficiency

4.4 Air–Fuel ratio

Air fuel ratio is defined as ratio of mass of air to that of mass of fuel present in a combustion process. Figure 4.4 shows the variation of air fuel ratio with brake power. Air fuel ratio for WCOME operation is lower compare to neat diesel. With the addition of GRAPHENE nanoparticles to WCOME increases the air fuel ratio. Since nanoparticles possess high surface to volume ratio and catalytic activity of the nanoparticles requires more amount of air than the neat biodiesel. Maximum increase in Air-fuel ratio of 3.41% for (WCOME+20ppm), 8.53% for (WCOME+40ppm) and 10.98% for (WCOME+60ppm) blended fuel as compared to WCOME at full load was observed.

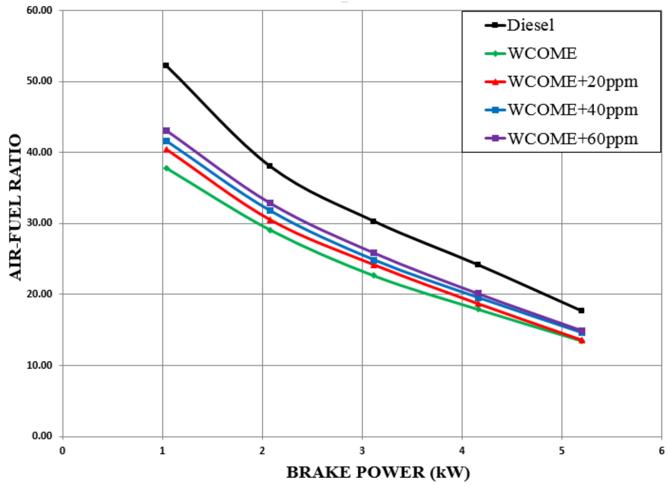

Figure 4.4: BP vs Air–Fuel ratio

Emission parameters

4.5 Smoke Density

Figure 4.5 shows the variation of smoke density with brake power for diesel, biodiesel and nano biodiesel blends. It is observed that the brake power increases, the smoke density gradually increases in all cases. The WCOME results in higher smoke density compared to diesel due to its heavier molecular structure and lower volatility [1]. The addition of nanoparticles significantly reduces smoke density with respect to WCOME for all the loads. This is due to shorter ignition delay characteristics of WCOME-GRAPHENE blende fuels. Smoke density is lower for WCOME+60ppm compare to WCOME+20ppm this is due to the molecular structure and volatility may improve because the high dosage of WCOME+60ppm compared to that of WCOME+20ppm. There is a reduction in smoke emission of 2.85% for (WCOME+20ppm), 5.88% for (WCOME+40ppm) and 9.09% for (WCOME+60ppm) blended fuel as compared to WCOME at part load was observed.

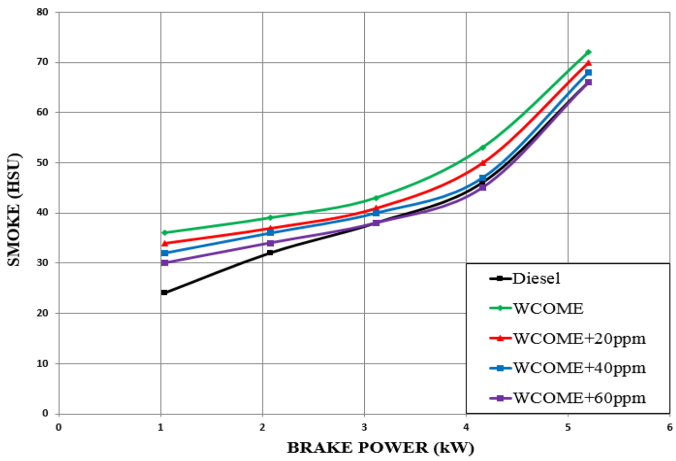

Figure 4.5: BP vs Smoke Density

4.6 Hydrocarbon

The unburnt HC emissions for diesel, WCOME, and WCOME-GRAPHENE blended fuels are shown in Figure 4.6. The HC emission for WCOME operation is higher compared to neat diesel due to its lower thermal efficiency resulting in abnormal combustion [1]. The HC emissions gradually decreases with the addition of GRAPHENE nanoparticles to WCOME due to catalytic activity and better combustion characteristics of GRAPHENE nanoparticles which leads to enhanced combustion. A GRAPHENE nanoparticle increases the catalytic activity and chemical activity which leads to complete combustion of fuel. WCOME+60ppm gives better performance as compared to WCOME+20ppm due to the increased dosing level of GRAPHENE nanoparticles. That provides higher surface area which leads to greater combustion characteristics [11]. It was observe that 4.47% for (WCOME+20ppm), 7.69% for (WCOME+40ppm) and 9.30% for (WCOME+60ppm) reduction in HC emission as compared to neat WCOME.

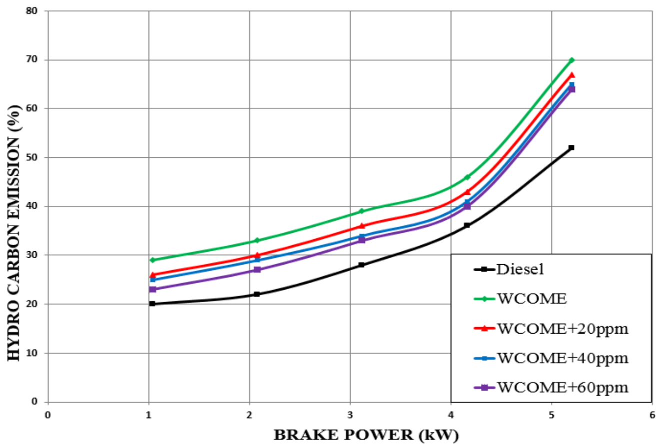

Figure 4.6: BP vs Hydrocarbon

4.7 Carbon Monoxide

The CO emissions for Diesel, WCOME and WCOME-GRAPHENE blended fuels are shown in Figure 4.7. The CO emission for WCOME operation is higher compared to diesel due to its lower thermal efficiency resulting in partial combustion. The CO emissions are slightly lower for the WCOME-GRAPHENE nanoparticle blended fuels than WCOME due to catalytic activity and better combustion characteristics of GRAPHENE nanoparticles which leads to improved combustion [1]. The CO emissions were lower for WCOME+60ppm nanoparticle blended fuels compare to other nanoparticle blended fuels. This is due to higher catalytic activity and enhanced combustion characteristics of WCOME+60ppm blended fuels. GRAPHENE nanoparticles have higher thermal conductivity, higher surface area for catalytic activity and showed enhanced results as compared to the neat biodiesel [10]. The CO emissions for diesel fuel operation were lower than the neat biodiesel and GRAPHENE nano-biodiesel blended fuels. Hence significant reduction in CO emission was observed for Nano blends as compared to WCOME. There is a reduction in CO emission of 7.5% for (WCOME+20ppm and WCOME+40ppm) and 10% for (WCOME+60ppm) blended fuel as compared to WCOME at part load was observed.

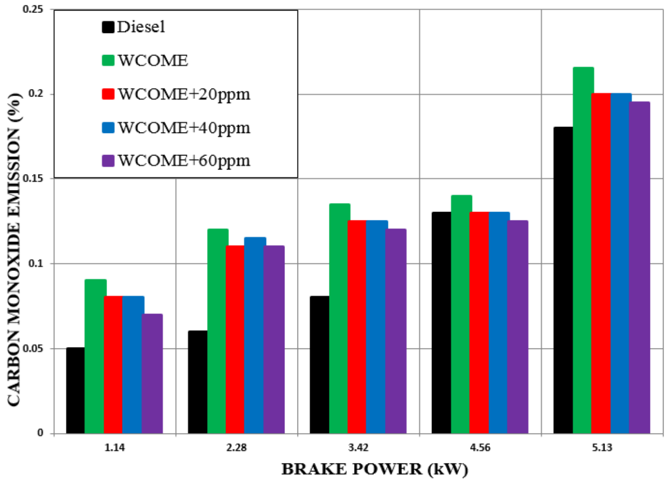

Figure 4.7: BP vs Carbon Monoxide

4.8 Oxides of Nitrogen

Figure 4.8 above shows variation of NOx emission for Diesel, WCOME and WCOME-GRAPHENE blended fuel. WCOME shows lower NOx emissions compared to neat diesel operation. Heat release rates of WCOME were lower during premixed combustion phase, which lead to lower peak temperatures. NOx formation mainly depends on peak temperature, WCOME GRAPHENE nanoparticle blended fuels produced higher NO*x* emission compared to that of WCOME. The reason for increase in NOx may be attributed to higher combustion temperatures arising from better combustion due to improved mixture formation and availability of oxygen for diesel fuel.

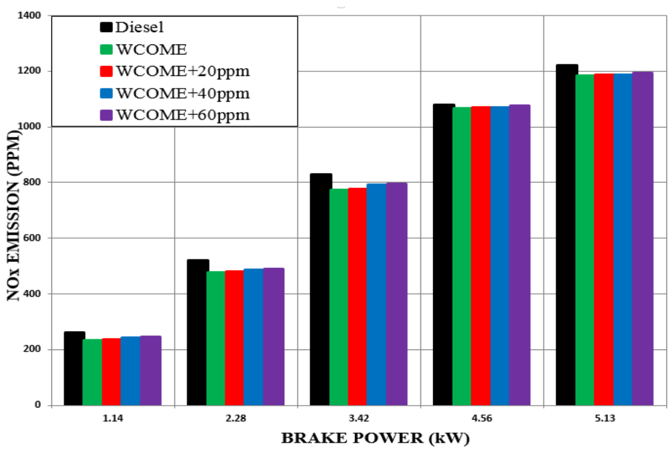

Figure 4.8: BP vs Oxides of Nitrogen

5. CONCLUSIONS

The performance and emission characteristics of a single cylinder four stroke diesel engine using neat WCOME fuel and GRAPHENE blended WCOME fuels were investigated. Based on the experimental investigations, the following conclusions are drawn.

- GRAPHENE blended biodiesel (WCOME+20ppm, WCOME+40ppm and WCOME+60ppm) shows an improvement in the calorific value and reduction in flash point as compared to neat WCOME.
- Neat WCOME has higher brake specific fuel consumption, because of its lower heating value. With the addition of GRAPHENE nanoparticles, there is significant reduction in fuel consumption as compared to WCOME was observed.
- A major increase in brake thermal efficiency was observed with the addition of GRAPHENE nanoparticles to the neat WCOME.
- Addition of GRAPHENE nanoparticles to WCOME improves the combustion charactestics and catalytic activity of the fuel, and there by decreases the ignition delay during combustion process.
- Nano blended fuels reduce HC and CO emission as compared to neat biodiesel. Also addition of GRAPHENE has no effect on NO_x emission.

It can be concluded that higher dosage of nanoparticle addition i.e. 60 ppm to WCOME might further increase the diesel engine performance.

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