Graphene Nanoparticle - Biodiesel Blended 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 for base line data generation and graphene nanoparticle blended – biodiesel. The biodiesel was prepared from honge raw oil called Honge Oil Methyl Ester [HOME]. The graphene nanoparticles were blended with the biodiesel fuel in the mass fractions of 25ppm and 50 ppm with the aid of a mechanical homogenizer and 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 diesel engine coupled with an eddy current dynamometer loading device and the results revealed that a considerable higher enhancement in the brake thermal efficiency and substantial 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, HOME, Biodiesel, graphene nanoparticle-biodiesel blends, Ultrasonicator, and Emission.**

I. INTRODUCTION

The diesel engines have their special advantages like durability, reliability and fuel economy then gasoline engines. Diesel engines cause higher emission of particulate matter (PM), carbon monoxide (CO), Hydrocarbon and nitric oxides causing various global hazards such as climatic Change, ozone layer depletion, green house effect, global warming, and smog acid rain water bodies and reduce in air quality. Due to the increased hazardous effects of emission from engine, to reduce these effects many researchers have contributed their work by different ways like engine modification, fuel alteration exhaust gas treatment [1] In this way engines are operated with biodiesels without modification of previous engines. 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 include 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 [m^2/g], magnetic, electric properties, optical properties, reactivity, high surface to volume ratios and energy densities [1]. Graphene has attracted much attention from researchers due to 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 [1-4]. As a novel nanomaterial, graphene possesses unique electronic, optical, thermal, and mechanical properties. Yetter *et al*., [2] have critically reviewed the reports on metal nano-particles combustion and revealed that the nano-size metallic powders possess high specific surface area and potential to store energy, which leads to high reactivity. A single atomic layer of graphene is the thinnest sp2 allotrope of carbon. It, therefore, has various unique electrical and optical properties of interest to scientists and technologist [3]. Sabourin *et al.*, [4] have compared the combustion of the monopropellant nitromethane with that of nitromethane containing colloidal particles of functionalized graphene sheets. Catalytic activity of FGS is expected to occur on both sides of the graphene sheets. The fuel colloids studied, particularly ones containing FGSs, enhance the reaction rates through several mechanisms including enhanced heat transfer (radiation and conduction) and chemical reactivity (catalysis and carbon oxidation).The ignition temperatures were lowered and burning rates increased for the colloidal suspensions compared to those of the liquid monopropellant alone, with the graphene sheet suspension having significantly greater burning rates (*i.e.*, greater than 175%). Graphene is an exciting material. It has a large theoretical specific surface area, high intrinsic mobility, high Young's modulus and thermal conductivity and its optical transmittance (97.7%) and good electrical conductivity[5,6]. Sadhik Basha *et.al*.,[7,8] have used alumina and carbon nanotubes nanoparticles as additives to the biodiesels. They concluded that the nano-particles can function as a catalyst and an energy carrier, as well. In addition, due to the small scale of nanoparticles, the stability of the fuel suspensions should be markedly improved. Arul *et al.*, [9] investigated diesel engine using cerium oxide nanoparticles. The cerium oxide acts as an oxygen donating catalyst and provides oxygen for the oxidation of CO or absorbs oxygen for the reduction of NOx.

II. HOME–GRAPHENE BLENDS PREPARATION.

The graphene nano particles will be weighted by using electronic balance. Then nanoparticles are weighed separately for quantities 25mg and 50mg accurately. The nanoparticles blended honge biodiesel fuel is prepared by mixing the honge 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 25ppm and dispersed in the honge biodiesel fuel the blend that prepared is called HOME25GRAPHENE. The same procedure is carried out for the mass fraction of 50ppm to prepare the graphene nanoparticles blended honge biodiesel fuel (HOME50GRAPHENE).

Figure 1: ultrasonicator

The samples of graphene nanoparticles blended honge biodiesel fuels are kept in bottles under static conditions for analysing the stability characters.

After the preparation of nanoparticle biodiesel blends properties like flash point, kinematic viscosity and calorific value of prepared blend were determined using particu lar apparatus are follows

Sr. no.	Engine specification	
	Parameters	Engine
1	Type of engine	Kirlosker make Single cylinder four stroke direct injection diesel engine
2	Nozzle opening pressure	200 to 205 bar
3	Rated power	5.2 KW (7 HP) @1500 RPM
4	Cylinder diameter (Bore)	87.5 mm
5	Stroke length	110 mm
6	Compression ratio	17.5 : 1

Table 1: Properties nanoparticle-biodiesel blends.

The table below shows properties of graphene nanoparticles used for present work

Sr. No	Parameters	GRAPHENE NANOPARTICLES
1	Manufacturer	Karnataka University Dharwad
2	Bulk/ true density – g/cc	-----
3	Average particle size (APS) – nm	22.5-26
4	Surface area (SSA) m^2/g	492
5	Purity - %	99.7
6	Thermal conductivity – W/mK	3000

Table 2: Properties of nanoparticles used for present study.

III. RESULTS AND DISCUSSIONS

During the experiment, injection timing, injection opening pressure and compression ratio were kept at 23^o bTDC, 205 bar and 17.5 for diesel operation and 19^0 bTDC, 230 bar and 17.5 for HOME –graphene nanoparticle blend.

Figure 2: Experimental test rig

Table below shows the Spcifications of engine used for present worktable

Type of fuel	Flash point ^{o}C	Kinematic Viscosity, cSt @ 40 ^{o}C	Net calorific value, MJ/kg	Density @15 ^{o}C
Diesel	56	2 -3	43	840
HOME	170	5.6	36.016	880
HOME25 GRAPHENE	160	5.8	35.00	895
HOME50 GRAPHENE	158	5.8	35.50	900

3: Specification of test.

A. Variation of brake thermal efficiency

Figure shows variation of brake thermal efficiency for Diesel, HOME and HOME-GRAPHENE blended fuels. The HOME results in inferior performance due to its higher viscosity and lower volatility and lower calorific value. However the brake thermal efficiency of the HOME-GRAPHENE blended fuels is improved compared to neat HOME operation. This could probably be attributed to the better combustion characteristics of HOME-GRAPHENE. In general, the nanosize particles possess high surface area and reactive surfaces that contribute to higher chemical reactivity to act as a potential catalyst. In this perspective, the catalytic activity of HOME-GRAPHENE could have improved due to the existence of high surface area and active surfaces. Moreover, in case of HOME50GRAPHENE fuel, the catalytic activity may enhanced due to the high dosage of compared to that of and HOME25GRAPHENE. Due to this effect, the brake thermal efficiency is higher for HOME50GRAPHENE compared to that of HOME25GRAPHENE. The maximum brake thermal efficiency for HOME50GRAPHENE is 26 percent, compared to 24% for HOME and 28.0 for neat diesel, at the 80% load respectively.

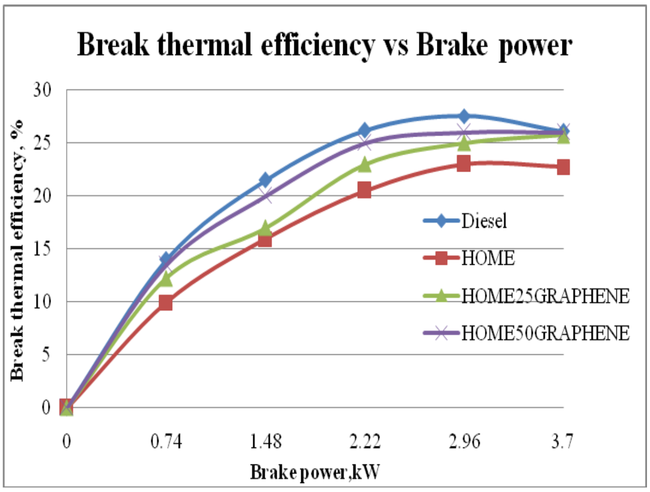

Figure 3: Variation of Break thermal efficiency.

B. Variation of smoke opacity

The smoke opacity for Diesel, HOME, HOME-GRAPHENE blended fuels shown is shown in Figure. The HOME results in higher smoke opacity compared to diesel due to its heavier molecular structure and lower volatility. However reduced smoke opacity is observed in the case of HOME-GRAPHENE blended fuels. This could be attributed to shorter ignition delay characteristics of HOME-GRAPHENE blended fuels. Moreover, in case of HOME50GRAPHENE fuel, the molecular structure and volatility may enhanced due to the high dosage of compared to that of and HOME25GRAPHENE. Due to this effect, smoke opacity is lower for HOME50GRAPHENE compared to that of HOME25GRAPHENE.

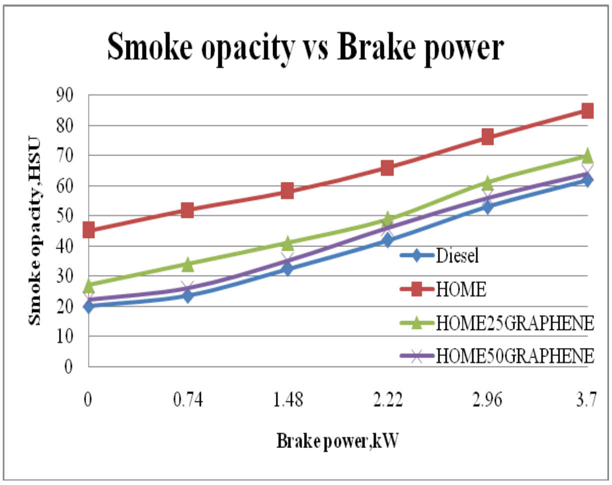

Figure 4: variation of smoke opacity.

C. Variation of HC emission

The unburnt HC emissions for HOME, HOME-GRAPHENE and HOME-MWCNTs blended fuels are shown in Fig. 7. The HC emission for HOME operation is higher compared to diesel due to its lower thermal efficiency resulting in incomplete combustion. However HC emissions are marginally lower for the HOME-GRAPHENE and HOME-MWCNTs blended fuels than HOME. This could be due to catalytic activity and improved combustion characteristics of GRAPHENE NPs and MWCNT, which leads to improved combustion. For the HOME –GRAPHENE blend reduced hydrocarbon emission as compared to HOME-MWCNTs blends due to graphene nanoparticles gives more surface area; it increases catalytic and chemical activity. Thus complete combustion of fuel takes place.

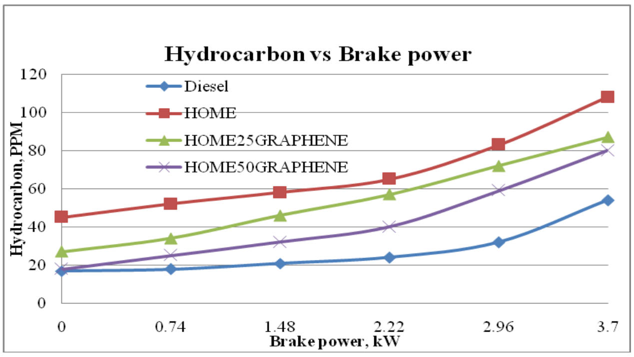

Figure 5: Variation of Hydrocarbon with brake power

D. Variation of CO emission

The CO emissions for Diesel, HOME and HOME-GRAPHENE blended fuels are shown in Figure. The CO emission for HOME operation is higher compared to diesel due to its lower thermal efficiency r sulting in incomplete combustion.

However CO emissions are marginally lower for the HOME-GRAPHENE nanoparticle blended fuels than HOME. The higher catalytic activity and improved combustion characteristics of HOME-GRAPHENE NPs as compared to HOME leading to less carbon monoxide for HOME-GRAPHENE nanoparticle blended fuel. Then increasing dosing level of nanoparticles in biodiesel

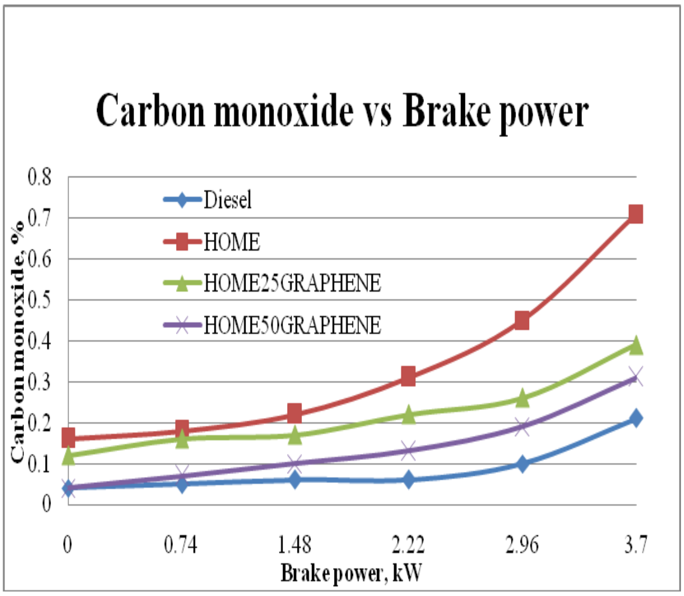

Figure 6: Variation of carbon monoxide with brake power.

E. Variation of NOx emission

Figure below shows variation of NOx emission for Diesel, HOME, HOME-GRAPHENE nanoparticle blended fuels. HOME shows lower NOx emissions compared to diesel operation. Heat release rates of HOME were lower during premixed combustion phase, which will lead to lower peak temperatures. Nitrogen oxides formation strongly depends on peak temperature, which explains the observed phenomenon. Furthermore, HOME GRAPHENE nanoparticle blended fuels produced higher NO*x* emission compared to that of HOME. The higher premixed combustion being observed with the HOME50GRAPHENE NPs blended fuel as compared to that of HOME25GRAPHENE blends.

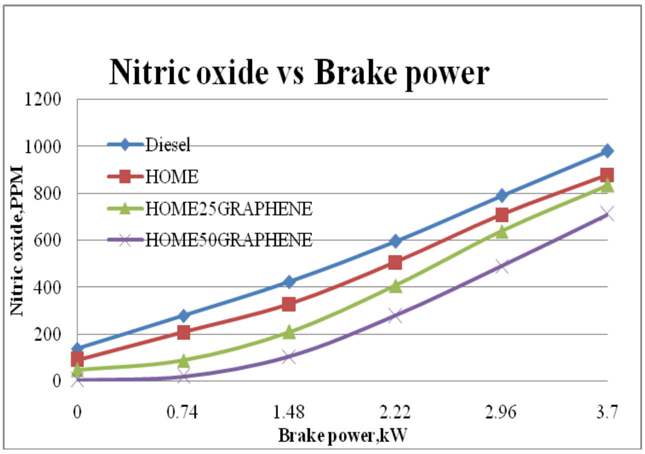

Figure 7: Variation of nitric oxide with brake power.

IV. CONCLUSION

The performance, and the emission characteristics of HOME, HOME-GRAPHENE blended fuels were investigated in a single-cylinder, constant speed, direct-injection diesel engine.

Based on the experimental data, the following conclusions were drawn.

1. HOME results in poor performance in terms of reduced brake thermal efficiency. However HOME performance was improved by adding nanoparticles. The brake thermal efficiency of HOME50GRAPHENE NPs blended fuel were higher compared to that of HOME25GRAPHENE blends due to higher dosing level graphene nanoparticles to biodiesel.
2. HOME results in poor performance in terms of increased smoke opaciton monoxide hydrocarbon emissions. This emission is drastically reduced with HOME50GRAPHENE NPs blended fues compared to that of HOME25GRAPHENE blend due to the increased dosage level of nanoparticles to the honge biodiesel.
3. NOx emission is lower for HOME as compared to the nanoparticle added honge biodiesel due to the Heat release rates of HOME were lower during premixed combustion phase, which will lead to lower peak temperatures. Nitrogen oxides formation strongly depends on peak temperature, which explains the observed phenomenon.

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