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EXPERIMENTAL INVESTIGATIONS ON A DIESEL ENGINE FUELLED WITH MULTIWALLED CARBON NANOTUBES BLENDED BIODIESEL FUELS

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ABSTRACT

Experimental investigations were carried out to determine performance, emission, and combustion characteristics of diesel engine using multi walled carbon nanotubes (MWCNTs) blended biodiesel fuels. The fuel combinations used for the study were neat diesel for base line data generation, and CNT blended –biodiesel. The biodiesel was prepared from honge oil called Honge Oil Methyl Ester [HOME]. The MCNTs were blended with the biodiesel fuel in the mass fractions of 25 and 50 ppm with the aid of a mechanical homogenizer and an ultrasonicator. Subsequently, the stability characteristics of MWCNT blended –biodiesel fuels were analyzed 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, an MRU 1600s five gas analyzer, a Hartridge smoke meter, and a data-acquisition system comprising a high pressure piezoelectric pressure sensor and a crank angle encoder. All the experiments were conducted at a constant speed of 1500 rpm and the results revealed that a considerable enhancement in the brake thermal efficiency and substantial reduction in the harmful pollutants due to the incorporation of MWCNTs in the biodiesel fuels were observed.

Keywords: Carbon nanotubes, Ignition delay, Diesel engine, Honge oil, HOME, Biodiesel, Ultrasonicator, Emission.

1. INTRODUCTION

The diesel engines are considered to be fuel efficient and sturdier than gasoline engines. However, they produce hazardous emissions such as oxides of nitrogen (NO_x), particulates of matter, smoke, and obnoxious odour in high magnitudes. To ameliorate the performance and to reduce the emissions from the diesel engines, various techniques such as fuel modification, engine design alteration, exhaust gas treatment, etc. have been tried. Several researchers have contributed their efforts on fuel modification techniques in which some chemical reagents are incorporated along with the conventional diesel fuel. One of the fuel modification techniques is the water–diesel emulsion, which comprises diesel, water, and surfactant in specific proportions. The water in the emulsion is suspended in the fuel by a suitable surfactant and does not allow the water to come into direct contact with the engine surface [1]. Many researchers have reported on various nano–particles for diesel engine applications. In view of this, many new approaches and advances in nano-technology are being directed to use nano-fuel as a potential secondary energy carrier [2]. Nano particle blended fuels are known to exhibit significantly different thermo physical properties when compared to base fuels. At nano meters scale the surface – area -to-volume ratio of the particle increases considerably and this enables a larger contact surface area during rapid oxidation process [3]. For instance, due to size-dependent properties, energetic materials containing nano-particles can release more than twice the energy of even the best molecular explosives [4]. Several studies have reported lower melting points and lower heats of fusion for decreasing sizes of metal particles [5, 6, 7]. Yetter *et al*. [8] 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. In their detailed report on nano-particle combustion, they have stated that adding nano-catalyst to the hydrocarbon fuels (such as diesel) will reduce the ignition delay and soot emissions.

2. USE OF MULTIWALLED CARBON NANO TUBES (MWCNT's)

Marquis and Chibante's [10] work on carbon nano-tubes (CNT) indicated that the suspended CNT in a base fluid will enhance the surface-area-to-volume ratio and settling time. Based on the above literature on the potential applications of CNT, Sadhik Basha and Anand [11] have experimentally investigated the performance and the emission characteristics of a diesel engine using CNT blended diesel. They observed a substantial enhancement in the brake thermal efficiency and reduced harmful pollutants compared to that of neat diesel. This is assumed to be due to better combustion. The same team have critically reviewed the applications of nano-particle/nano-fluid in diesel engines and concluded that adding suitable proportion of nanoparticles/CNT to the conventional fuels such as diesel will reduce the evaporation time, which in turn favours shorter ignition delay. Owing to the potential properties of nano-particles/CNT, the present work is aimed at establishing the effects on the performance, emission, and combustion characteristics of a single-cylinder, direct-injection diesel engine using CNT blended water–diesel emulsion fuel. Therefore, 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.

Recently, Sajith *et al*. [9] conducted an experiment in single-cylinder diesel engine by dosing ceria nanoparticles (20–80 ppm) to the jatropha biodiesel and found a significant reduction in NO*x* and HC levels, and improvement in the brake thermal efficiency. They also observed that adding ceria nano-particles to the base fuel acts as an oxygen buffer, which leads to high catalytic combustion activity owing to their enhanced surface-area-to-volume ratio characteristics [8]. Kao *et al*. [7] carried out an experimental investigation in a single-cylinder diesel engine using aluminium nanoparticles blended diesel with varying water concentration and found significant improvement in the performance characteristics and substantial reduction in the harmful pollutants level of smoke and NO*x* due to the effect of improved combustion [9].

3. EXPERIMENTAL SET UP

The experimental investigations were carried out in two phases. In the first phase, the various physicochemical properties of modified bio diesel were determined and compared with those of the base fuels. The properties studied were the flash point, kinematic viscosity, calorific value, pour and cloud points. In the second step extensive performance, combustion and emission tests were conducted on a single cylinder four stroke direct injection compression ignition engine using the modified and base fuels. Figure 1 shows the schematic experimental set up. Eddy current dynamometer was used for loading the engine. The fuel flow rate was measured on the volumetric basis using a burette and stopwatch also. The emission characteristics were measured by using HARTRIDGE smoke meter and AVL make equipment during the steady state operation. The tests were conducted with diesel, and HOME – nano particle blends combination and compared with diesel operation. The specification of the compression ignition (CI) engine was given in Table 1. Injection timing and injection pressure for diesel and HOME – MWCNT operation are kept at their optimum conditions, viz. 23° BTDC and 230 bar for diesel and 19 ° BTDC, 230 bar for HOME- MWCNT blend. The method of preparation of the fuels with the MWCNT along with the experimental methods for obtaining the fuel properties are given in the Table 2 and 3.

Fig. 1 Experimental set up

Table 1 Specification of test rig

Sl 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 2 Material properties of nano – particle samples used in this study**.**

Sl.no	Parameters	CNT
1	Manufacturer	Intelligent Pvt. Ltd
2	Bulk/ true density – g/cc	0.05 – 0.17
3	Average particle size (APS) - nm	10 – 30 Length - 1–2 µm
4	Surface area (SSA) m^2/g	350
5	Purity - %	95

Table 3 Properties of HOME **-** nano – particle blend samples used in this study

Type of fuel	Density @15 ^oC
Diesel	840
HOME	880
HOME25CNT	898
HOME50 CNT	900

Type of fuel	Flash point, ^{o} C	Kinematic Viscosity, cSt @ 40 ^{o}C	Net calorific value, MJ/kg
Diesel	56	2 -3	43
HOME	170	5.6	36.016
HOME25CNT	166	5.7	34.56
HOME50 CNT	164	5.8	35.10

4. HOME – MWCNT BLENDS PREPARATION

In the first step, the CNT are weighed to a predetermined mass fraction of 25ppm and dispersed in HOME (5 per cent by volume) using ultrasonicator set at a frequency of 40 kHz, 120W for 30 min. This, the CNT blended – HOME fuel is prepared and the same process is carried out for the mass fraction of 50ppm CNT blended biodiesel fuel.

5. 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 – MWCNT blend respectively.

5.1 VARIATION OF BRAKE THERMAL EFFICIENCY

Fig. 2 shows variation of brake thermal efficiency for HOME and HOME-MWCNTs blended fuels. The HOME operation resulted in inferior performance due to its higher viscosity (nearly twice diesel) and lower volatility and lower calorific value.

However the brake thermal efficiency of the MWCNTs-HOME blended fuels was observed to be better compared to neat HOME operation. This could probably be attributed to the better combustion characteristics of MWCNTs. In general, the nanosize particles possess high surface area and reactive surfaces that contribute to higher chemical reactivity to act as a potential catalyst [**22**]. In this perspective, the catalytic activity of MWCNTs could have improved due to the existence of high surface area and active surfaces. Moreover, in case of HOME50MWCNT fuel, the catalytic activity may be enhanced due to the high dosage of MWCNT compared to that of HOME25MWCNT. Due to this effect, the brake thermal efficiency is higher for HOME50MWCNT compared to that of HOME25MWCNT. The maximum brake thermal efficiency for HOME50MWCNT is 25.0% whereas it is 24% for HOME25MWCNT, compared to 23% for HOME and 28% for neat diesel, at the 80% load respectively.

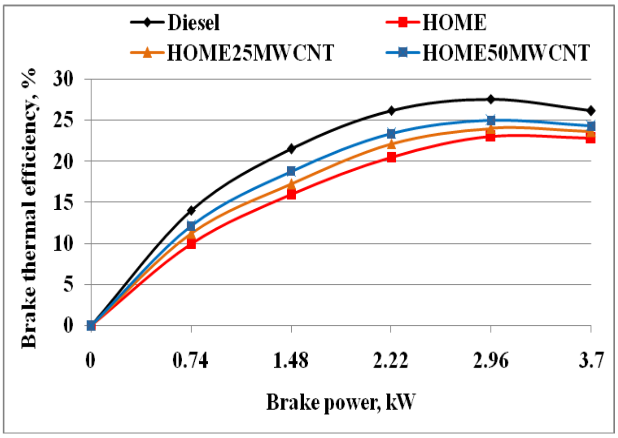

Fig. 2 Variation of brake thermal efficiency with brake power

5.2 VARIATION OF SMOKE OPACITY

The smoke opacity for HOME and HOME-MWCNTs blended fuels shown is shown in Fig. 3. The HOME operation resulted 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 MWCNTs-HOME blended fuels. This could be attributed to shorter ignition delay characteristics of MWCNTs-HOME blended fuels. The smoke opacity for HOME50MWCNT is 59 HSU whereas it is 63 HSU for HOME25MWCNT, compared to 78 HSU for HOME and 52 HSU for neat diesel, at the 80% load respectively.

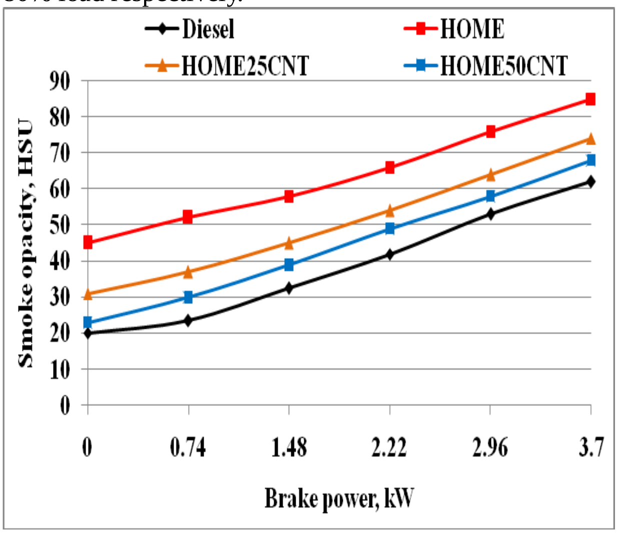

Fig. 3 Variation of smoke opacity with brake power

5.3 VARIATION OF HC EMISSION

The unburnt HC emissions for HOME and HOME-MWCNTs blended fuels are shown in Fig. 4. 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-MWCNTs blended fuels than HOME. This could be due to catalytic activity and improved combustion characteristics of MWCNT, which leads to improved combustion.

The HC emission for HOME50MWCNT is 58 PPM whereas it is 70 PPM for HOME25MWCNT, compared to 82 PPM for HOME and 32 PPM for neat diesel, at the 80% load respectively.

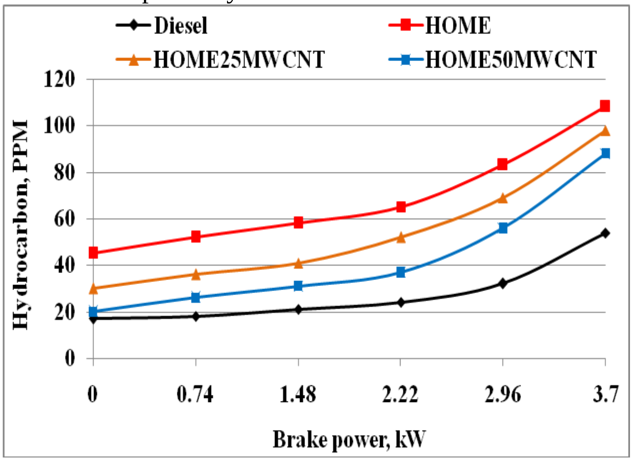

Fig. 4 Variation of hydrocarbon with brake power

5.4 VARIATION OF CO EMISSION

The CO emissions for HOME and HOME-MWCNTs blended fuels are shown in Fig. 5. The CO emission for HOME operation is higher compared to diesel due to its lower thermal efficiency resulting in incomplete combustion.

However CO emissions are marginally lower for the HOME-MWCNTs blended fuels than HOME. The higher catalytic activity and improved combustion characteristics of MWCNT, leading to improved combustion could be the reason for this performance. CO emissions for HOME50MWCNT are 0.21% whereas it is 0.3% for HOME25MWCNT, compared to 0.45% for HOME and 0.1 for neat diesel, at the 80% load respectively.

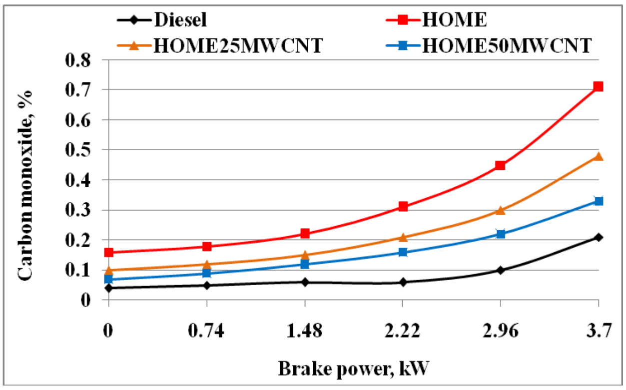

Fig. 5 Variation of carbon monoxide with brake power

5.5 VARIATION OF NOX EMISSION

Fig. 6 shows variation of NOx emission for HOME and HOME-MWCNTs blended fuels. For HOME operation NOx emissions were lower as 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-MWCNTs blended fuels produced higher NO*x* emission compared to that of HOME. This is because of reduced ignition delay that resulted in higher premixed combustion fraction and higher peak temperatures observed with HOME-MWCNT blends. The NOx emission for HOME50MWCNT is 750 PPM whereas it is 600 PPM for HOME25MWCNT, compared to 580 PPM for HOME and 800 PPM for neat diesel, at the 80% load respectively.

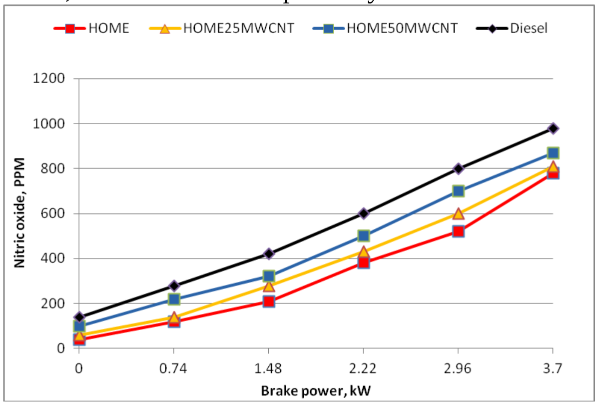

Fig. 6 Variation of nitric oxide with brake power

6. CONCLUSIONS

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

Based on the experimental data, the following conclusions have been drawn.

1. The brake thermal efficiency HOME-MWCNTs blended fuels were relatively better as compared to that of HOME.
2. HOME operation resulted in poor performance in terms of increased smoke, HC, CO emissions as compared to neat diesel operation.
3. The NOx emissions were relatively less for HOME as compared to that of HOME-MWCNTs blended fuels operation.
4. Ensuring higher dispersion of MWCNTs in HOME is still a subject of research. The study is limited to maximum of 50 ppm of MWCNTs.

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