Performance and Emission Characteristics of Nano Biodiesel Blends Fuelled With Diesel Engine

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Abstract - *In the present work, dairy scum methyl ester (DSME) biodiesel is used as an alternative to diesel fuel. Multi walled carbon Nano tube (MWCNTs) Nanoparticles were added to the dairy scum biodiesel to prepare Nano-blends. Ultrasonicator & Bath sonicator were used to prepare Nano-blends. Nano additives used in the blends were varied in mass fraction of 20ppm, 40ppm & 60 ppm. Physical and chemical properties of pure biodiesel and Nano blends were evaluated. Engine performance and emission tests were carried out on direct injection diesel engine. From the results it can be concluded that DSME + 60ppm MWCNT shows higher BTE and lower BSFC and also reduced exhaust emissions when compared DSME+20ppm and DSME+40ppm MWCNT blended biodiesel.*

***Key Words*: DSME biodiesel, MWCNT Nanoparticles, ultrasonicator, bathsonicator.**

1. INTRODUCTION

Owing to the depletion of the conventional fuels in recent days, it is essential to discover an alternative resolution to satisfy the energy demand required by the world. Many research works are going on to replace the diesel with a suitable alternate fuel such as biodiesel. Biodiesel is the best alternate fuel to satisfy the energy demand required by the world [1]. Biodiesel is a non-toxic, renewable, and biodegradable fuel, can either be used in diesel engines in pure or the form of blend without requiring any modifications to the engine. In general, biodiesel tends to increase the performance and reduces emission characteristics of CI engines [2, 3]. However, such usage of biofuels in diesel engines has met various practical problems; e.g. high viscosity, polymerization during storage and combustion, gum formation due to oxidation, acid composition, free fatty acid content, lubricating oil thickening and carbon deposits which are amongst the various problems reported by researcher[4]. 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 advance in materials science have directed to exciting possibilities in the development of propulsion of fuels. These include Nanoparticles, carbon nanotubes, graphene, and reactive nano composite 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. Among which Multi Walled Carbon Nano Tube (MWCNTs) has attracted much attention from researchers due to its interesting mechanical, electrochemical and electronic properties. CNT belongs to family of Nano materials made up completely of carbon. Basically MWCNTs consist of several layers (6 to25 layers) of graphite covered and rolled in them to form a tubular shape. Carbon Nano tubes (CNTs) have diameter in few nanometer and length in few microns with predicted thermal conductivity was 3000W/mK for MWCNTs, 6000 W/mK for SWCNTs [5]. Application of Carbon nano-tubes (CNT) in a base fluid enhances the surface to volume ratio & settling time. J. Sadhik Basha & R.B. Anand et al [6] to establish the effect of CNT on Jatropha Methyl Esters (JME) they were conducted experiments on 4-stroke single cylinder diesel engine. They concluded that there was 24.8% improvement in BTE for only JME fuel, whereas 26.34% and 28.45% for JME2S5W (93% Jatropha Methyl Esters+2% Surfactant +5% Water) and JME2S5W100CNT (93% Jatropha Methyl Esters + 2% Surfactant+5%Water+100ppm CNT) fuels respectively. This is due to combined effect of secondary atomization and micro-explosion of JME blended with CNT nanoblends C. Syed Aalam et al. [7] they conducted experiments on single cylinder 4-stroke common rail direct injection (CRDI) engine using 25% zizipus jujube methyl ester with 25ppm, 50ppm Al_2O_3 nanoparticles. They have concluded that Al_2O_3 blended fuel exhibit considerable reduction in SFC and emissions at all loads. At full load, the emission levels of HC and smoke for the ZJME25 before the addition of aluminium oxide nanoparticles was 13.459 g/kW h and 79 HSU, whereas it was 8.599 g/kW h and 49 HSU for the Al_2O_3 50 blended ZJME25 fuel respectively. M. Mirzajanzadeh et al. [8] observed the effects of addition of hybrid Nano catalyst (CeO_2 + Multi walled carbon nanotube MWCNT) in diesel and waste cooking oil methyl ester blends (B5 and B20) with proportion of 30, 60 and 90 ppm. There is a 7.81% and 4.91% increase in power and torque was observed for B20

(90ppm) as compared to B20. The MWCNT acts as support for CeO_2. The MWCNTs acts as accelerating catalyst for burning rate which resulted in reduced ignition delay. The CeO_2 act as oxygen contributing catalyst which oxidizes CO into CO_2 and absorb oxygen for reduction of NOx into nitrogen.

1.1 Objectives of the study

- To prepare MWCNTs nanoparticle and dairy scum methyl ester (DSME) blends in varying mass fraction of 20ppm, 40ppm, 60ppm with the aid of probe-sonicator and homogenizer.
- Estimation of properties of varying Nano-biodiesel blends and comparison with diesel.
- To check the replacement capacity of Nano blends to replace the diesel fuel.
- To study the suitability of the Nano-blends by running with diesel engine.
- To conduct performance and emission test and evaluation of results with respect to standard fuels.

2. MATERIALS AND METHODS

For the present work dairy scum methyl ester (DSME) is selected as an alternative to diesel fuel. Multi walled carbon nanotube (MWCNTs) nanoparticles as an additive to the DSME with the help of ultrasonicator and bathsonicator.

2.1 Properties of MWCNT nanoparticles

A carbon nanotube (CNTs) belongs to family of Nano materials made up completely of carbon. There are two types of CNTs, single-walled carbon nanotubes (SWCNTs) and multi–walled carbon nanotubes (MWCNTs). Basically MWCNTs consist of several layers (6 to25 layers) of graphite covered and rolled in them to form a tubular shape. CNTs have diameter in few nanometers and length in few microns with predicted thermal conductivity was 3000W/mK for MWCNTs, 6000W/mK for SWCNTs. These small dimensions of carbon nanotubes, combined with their amazing mechanical, electrical and physical properties, make them unique materials. Depending on how the carbon leaf is wound on itself they exhibit metallic or semi conductive properties. The current-density carrying capacity of nanotubes is very high and can reach one billion amperes per square meter making it a superconductor. Mechanical strength of carbon nanotubes is sixty times greater than the best steels. CNT have a great capability for molecular absorption and offers a 3-D configuration also they are chemically very stable. They have much surface area per unit mass with less density. Application of CNT in a base fluid enhances the surface to volume ratio & settling time. [9].

Table -1: Properties of MWCNTs

Sl. No.	Parameters	MWCNTs Nano particles
1	Manufacturer	Intelligent Pvt Ltd
2	Average particle size(APS), nm	10-30, length 1-2, thick
3	Bulk/ true density, g/cc	0.05-0.17
4	Surface area(SSA), m^2/g	350
5	Thermal conductivity, W/mK	3180
6	Purity (%)	95

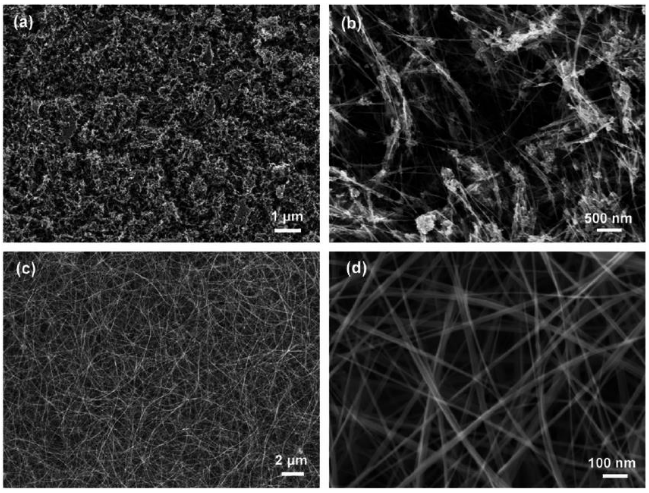

Fig -1: SEM images of (a) the cathode deposit (b) the enlarged section of deposit (c) the purified MWCNTs and (d) the purified MWCNTs in high-magnification.

2.2 Preparation of Nano biodiesel blends

The nano-particles blended dairy scum biodiesel fuel is prepared by mixing the DSME and MWCNTs particles with the aid of an ultrasonicator. The ultrasonicator technique is the best suited method to disperse the MWCNTs nano-particles in the base fuel, as it facilitates possible agglomerate nanoparticles back to nanometer range. The Nanoparticles are weighed to a predefined mass fraction say 20ppm and dispersed in the DSME with the help of ultrasonicator set at a frequency of 40 kHz for 30 minutes. The resultant nanoparticles blended dairy scum biodiesel is named as DSME+20MWCNTs. The same procedure is carried out for the mass fraction of 40 ppm and 60ppm to prepare the MWCNTs nanoparticles blended DSME biodiesel fuel (DSME+40MWCNTs, DSME+60MWCNTs). For analyzing Stability characteristics the blends were kept in bottles under static conditions.

Fig -2: Ultrasonicator

2.3 Blending Procedure

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

Table -2: Properties of Nano biodiesel blends

Type of fuel	Flash point ^0C	Fire point ^0C	Kinematic viscosity cSt @ 40 ^0C	Den sity Kg/ m^3	Calorif ic value MJ/kg
Diesel	56	61	3	840	43.0
DSME	129	137	4.6	872	35.85
DSME+20 MWCNT	115	121	5.32	886	37.11
DSME+40 MWCNT	111	119	5.67	893	37.66
DSME+60 MWCNT	106	113	5.91	901	38.20

Fig -3: Bathsonicator and dispersion of MWCNT

Fig -4: Prepared 20, 40, 60 ppm Nano biodiesel blends

3. EXPERIMENTAL SETUP

The engine performance and emission tests were carried out on 4 – stroke, single cylinder water cooled direct injection compression ignition engine. It has compression ratio (CR) of 17.5:1 and rated power of 5.2 kW at 1500 rpm. The details of the engine are listed in table 3. The specified injection timing and injector opening pressure by the machine supplier was 23^0 BTDC and 205 bar respectively. Engine speed was controlled by the governor. The engine was provided with a hemispherical shaped combustion chamber with overhead valves operated through push rods. Cooling water circulates through cylinder head and jackets on the engine block. The cylinder pressure was measured by piezoelectric pressure transducer (sensor) which is mounted on the cylinder head. Exhaust gas analyser is used to measure the emissions from the engine. The analyser can measure HC, CO, NO_x and CO_2 emissions. Digital Hart ridge Smoke meter was used to measure Exhaust gas smoke density.

Fig -5: Photographic view of experimental setup

Table -3: Engine Specifications

Parameters	Specifications
Type	Kirlosker made
Nozzle opening pressure	200 -225 bar
No. of cylinders	Single
No. of strokes	Four stroke
Rated power	5.2 kW at 1500 rpm
Bore	87.5 mm
Stroke length	110 mm
Compression ratio	17.5:1
Loading Type	Eddy current Dynamometer

4. RESULTS AND DISCUSSION

4.1 Engine Performance Characteristics

4.1.1 Brake thermal efficiency (BTE)

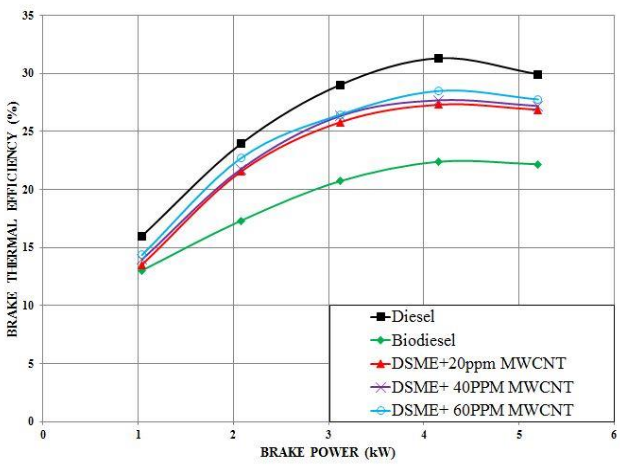

Fig -6: BP vs BTE

Fig-6 shows the variation of BTE with BP for diesel, DSME and Nano blends. The DSME shows poor performance due to its higher viscosity and lower calorific value than diesel, and high density causes poor atomization of fuel. However the BTE of Nano-blended fuels enhanced as compared to the neat biodiesel. DSME + 60 ppm MWCNT has higher BTE as compared to DSME + 20ppm MWCNT and neat biodiesel. This may be due to increased concentration of MWCNT nanoparticles and superior combustion characteristics of Nano-blended fuels. Since nanoparticles possess high surface to volume ratio resulting in good atomization and evaporation of fuel which improves the brake thermal efficiency. There is an increase in BTE of 21.24% (for DSME + 20 MWCNT), 22.6% (for DSME + 40MWCNT) and 24.94% (for DSME + 60 MWCNT) blended fuel as compared to base biodiesel at full load was observed.

4.1.2 Brake specific fuel consumption (BSFC)

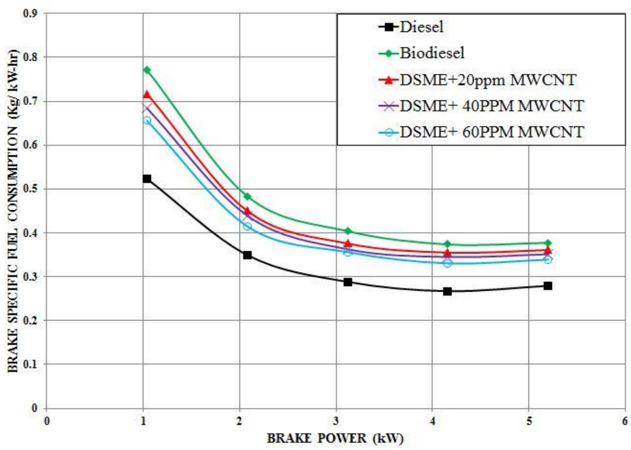

Fig -7: BP vs BSFC

The BSFC decreases with increase in BP for all fuels at all loads as shown in Fig 7. The BSFC is higher for neat biodiesel than Nano blends due to lower heating value of biodiesel. BSFC is lowest for DSME + 60 ppm Nano blend. This might be undoubtedly in the presence of MWCNT nanoparticles in the blend. It increases the calorific value and density. Also blends possess a higher surface to volume ratio for improved catalytic effect and hence less fuel is consumed during combustion. There is a reduction in BSFC of 4.72% (for DSME + 20 MWCNT), 7.71% (for DSME + 40MWCNT) and 14.24% (for DSME + 60 MWCNT) blended fuel as compared to base biodiesel at full load was observed.

4.1.3 Volumetric efficiency

Volumetric efficiency is defined as ratio of actual volume flow rate of air into the intake system to rate at which volume is displaced by the system. It is obvious to decrease since mass of air which enters the cylinder decrease with decrease in concentration of the MWCNT nanoparticles in the biodiesel as shown in Fig 8. Also the mass of air which is inducted into the cylinder has lower density therefore it needs more mass to occupy the volume of the cylinder which ultimately decreases

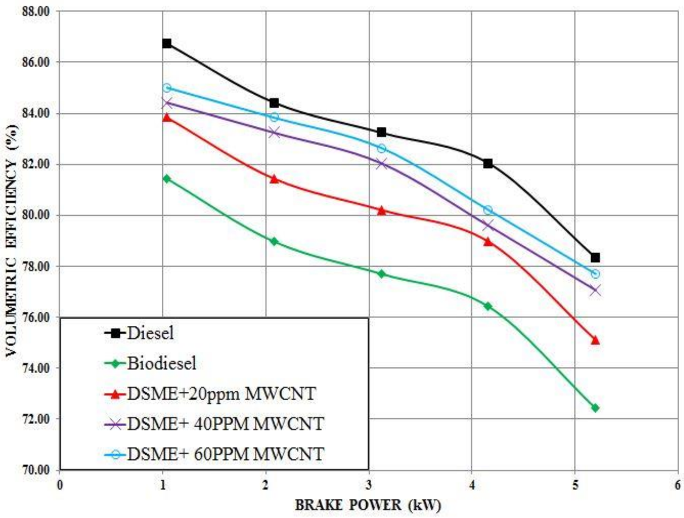

Fig -8: BP vs volumetric efficiency

the breathing capacity of the engine. Volumetric efficiency is highest for DSME + 60 ppm MWCNT blend. There is an increase in volumetric efficiency of 3.7% (for DSME + 20 MWCNT), 6.4% (for DSME + 40MWCNT) and 7.28% (for DSME + 60 MWCNT) blended fuel as compared to base biodiesel at full load was observed.

4.1.4 Air - Fuel ratio

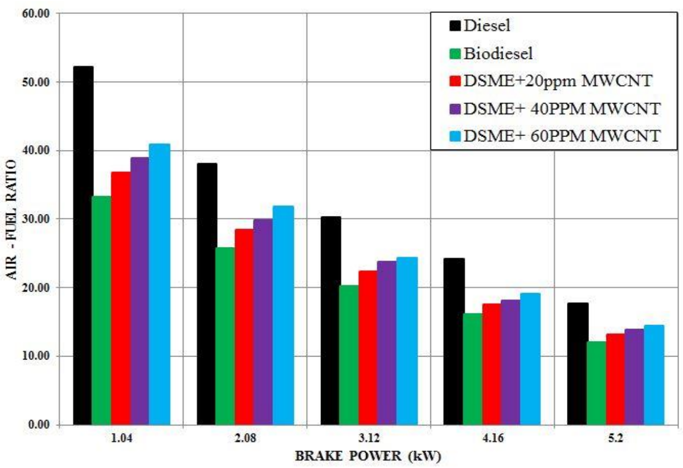

Fig -9: BP vs A/F ratio

Air - Fuel ratio is defined as ratio of mass of air to that of mass of fuel present in a combustion process. Fig 9 shows the variation of air-fuel ratio with brake power. The air-fuel ratio increases with increase in concentration of MWCNT nanoparticles in the blend at all loads. Since nanoparticles possess high surface to volume ratio and catalytic action of the nanoparticles requires more amount of air than the neat biodiesel. Maximum increase in A/F ratio of 8.52% (for DSME + 20 MWCNT), 14.32% (for DSME + 40MWCNT) and 19.37% (for DSME + 60 MWCNT) blended fuel as compared to base biodiesel at full load was observed.

4.1.5 Exhaust gas temperature (EGT)

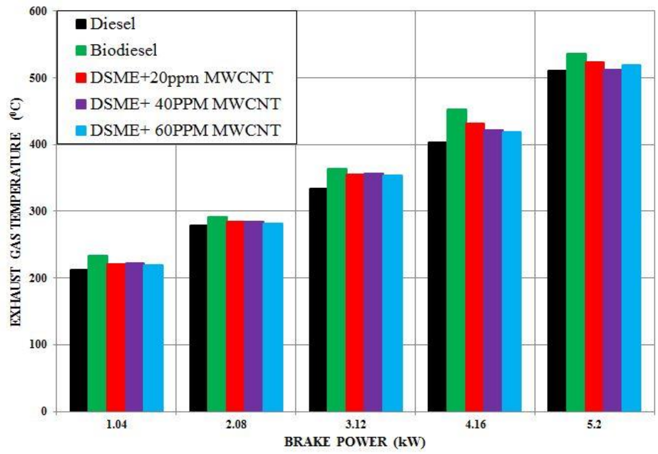

Fig -10: BP vs Exhaust gas temperature

Fig 10 shows the variation of exhaust gas temperature with brake power. It is evident that the exhaust gas temperature of the biodiesel and its blends is higher than the diesel. Out of which neat biodiesel has highest EGT as compared to others this may be due to the clean burning property of biodiesel. It can also be noticed from figure that EGT is almost constant for all Nano-blends since addition of MWCNT nanoparticles to biodiesel does not have significant effect on EGT.

4.2 Engine Emission Characteristics

4.2.1 Carbon Monoxide (CO)

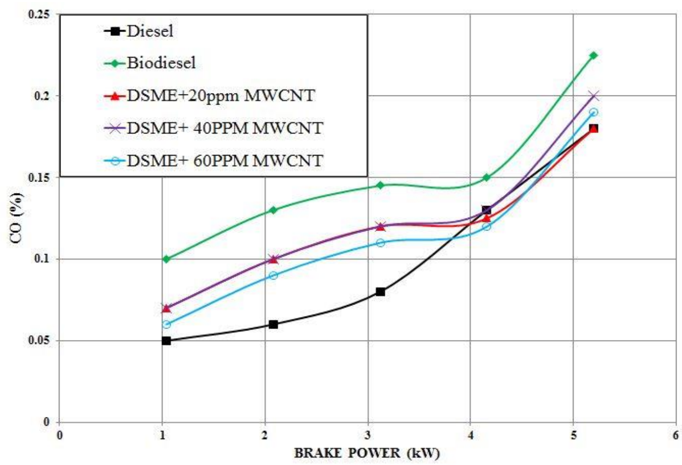

Fig -11: BP vs Carbon Monoxide

Fig 11 shows CO emission for DSME was higher as compared to DSME-Nano blended fuels. Because of ignition-delay problem and poor fuel–air mixing rate associated with DSME fuel resulted in incomplete combustion, and hence high CO emission. But, MWCNT blended fuels showed faster combustion due to the shortened ignition-delay period due to high thermal conductivity (3180 W/mK) and catalytic action of the MWCNT. A better fuel–air mixing rate and constant burning characteristics was observed in presence of MWCNT in the blends. Since MWCNT nanoparticles reduces the ignition delay effect and promotes complete combustion. Hence significant reduction in CO emission was observed for Nano blends as compared to DSME. There is a reduction in CO emission of 20.8% (for DSME + 20 MWCNT), 16% (for DSME + 40MWCNT) and 31.8% (for DSME + 60 MWCNT) blended fuel as compared to base biodiesel at part load was observed.

4.2.2 Hydrocarbon (HC)

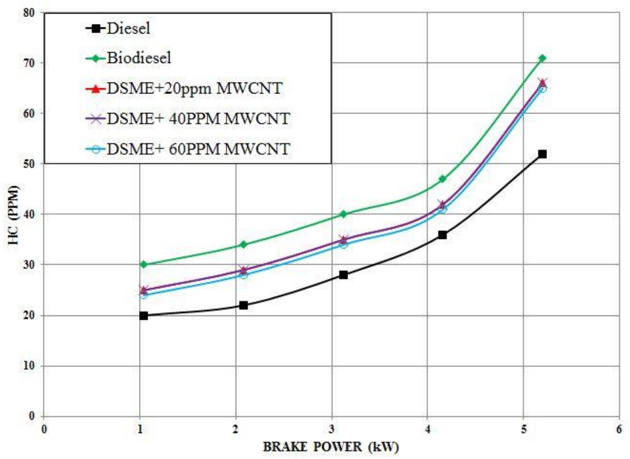

Fig -12: BP vs Hydrocarbon

From Fig 12 it is evident that, addition of MWCNT nanoparticles reduces the HC emission when compared DSME. MWCNT Nano additives act as combustion catalyst which promotes complete combustion. HC emission is highest for DSME due to lower brake thermal efficiency (Fig 6) which leads to incomplete combustion [7]. HC emission is almost same for DSME + 20ppm and 40ppm MWCNT blends. However hydrocarbon emission was considerably reduced for DSME + 60ppm MWCNT blend due to catalytic activity of MWCNTs at higher concentration. It is observed that 7.5% (for DSME+20ppm & 40ppm MWCNTs) and 9.2% (for DSME+20ppm MWCNT) reduction in HC emission as compared to neat DSME.

4.2.3 Oxides of Nitrogen (NOx)

NOx emission is primarily due to the combustion temperature and residence time. From Fig 13 it is observed that NOx emission was higher over entire load range for diesel. The cause for increase in NOx might be credited by higher combustion temperature arising from better combustion due to better mixture formation and availability of oxygen for diesel fuel. But NOx emission was almost constant for all proportions of Nano blends.Since MWCNTs particles present in the biodiesel has no significant effect on combustion temperature. However NOx emission was lower for DSME at low loads only.

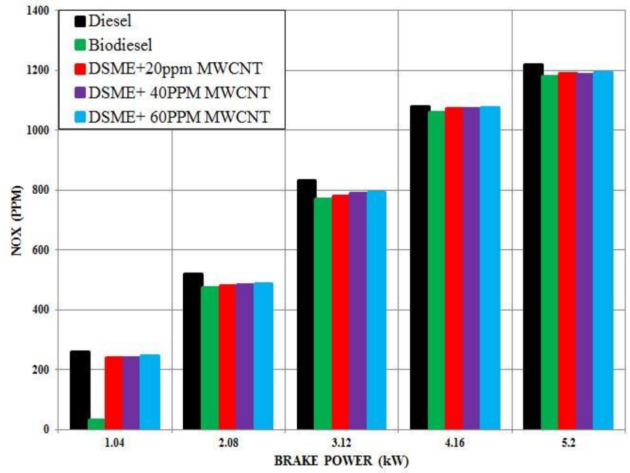

Fig -13: BP vs Oxides of Nitrogen

4.2.4 Smoke

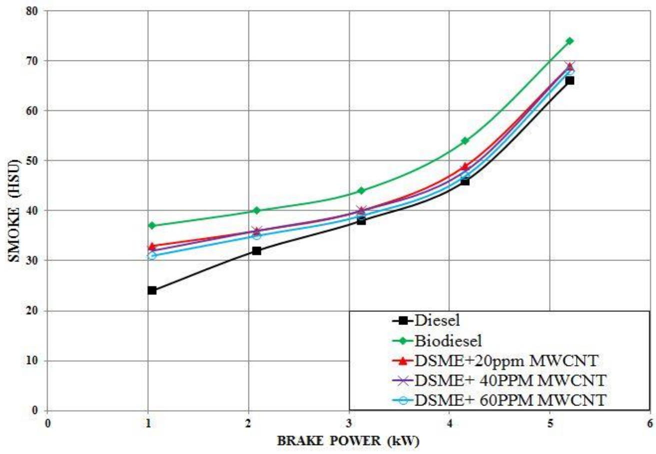

Fig -14: BP vs Smoke

Diesel engine exhaust contains solid carbon soot particles produced in the fuel-rich zone of the cylinder during combustion. These particles are seen as exhaust smoke. Black smoke is basically due to imbalance in A/F ratio i.e. Too much of fuel is being added to mixture but there is not enough oxygen to burn the fuel. The variation of smoke with brake power is shown in Fig 14. Lesser volatility and heavier molecular structure of DSME lead to higher smoke emission when compared to DSME + Nano-bends. On the other hand, the addition of MWCNT to the DSME reduces the smoke. This was probably due to the existence of reduced soot formation and better A/F mixture due to the rapid secondary atomization effects in the presence of MWCNT.

5. CONCLUSIONS

In the present study DSME and MWCNT blended fuels were fuelled with direct injection diesel engine and performance and emission characteristics were investigated. Based on the experimental investigations, the following conclusions were drawn:

1. MWCNT blended biodiesel (DSME+20, DSME+40 and DSME+60) shows an improvement in the calorific value and reduction in flash point as compared to neat DSME.
2. Neat biodiesel has higher brake specific fuel consumption, because of its inferior heating value. With the addition of MWCNT nanoparticles, there is appreciable reduction in fuel consumption as compared to DSME was observed.
3. A major increment in BTE was observed by adding MWCNTs nanoparticles to the biodiesel.
4. Ignition delay problem can be reduced by adding MWCNTs to DSME. This increases the catalytic action of the biodiesel and promotes complete combustion.
5. MWCNT - blended fuels showed considerable reduction in HC and CO emissions as compared to neat biodiesel. Also addition of MWCNT has no effect on NO_x emission.

Finally it is concluded that DSME + 60ppm MWCNT can be considered as an alternative to diesel fuel. Since adding MWCNT to DSME improves the BTE and reduces harmful emissions to a considerable level. Performance of diesel engine can be increased by increasing the concentration of nanoparticles (more than 50ppm). To achieve this better dispersion technique must be developed. However a serious work is going on to trap un-burnt MWCNT from diesel engine exhaust to safeguard global environment.

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