# Performance and emission characteristics of diesel engine fuelled with diesel and Karanja Methyl Ester blends with Multiwalled Carbon Nanotube

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***Abstract* - An experimental investigation was carried out to evaluate performance and emission characteristics of single cylinder, air cooled diesel engine running at constant speed of 1500 rpm using multiwalled carbon nanotube (MWCNT) blended diesel and karanja biodiesel. The multiwalled carbon nanotubes are blended with diesel and biodiesel in three different proportions of 50mg/lit, 100 mg/lit and 150 mg/lit. The stable and homogeneous blends of diesel and biodiesel with MWCNT were prepared using ultrasonic bath stabilizer. The whole experiment was carried out using following fuels: neat diesel, biodiesel and MWCNT blended diesel and biodiesel accordingly. The experimental results showed that addition of MWCNT in fuel results in improvement in the brake thermal efficiency and reduction in the brake specific fuel consumption. At full load, brake thermal efficiency for diesel and biodiesel was 29.13% and 23.30% respectively, where as it was 32.92% and 27.48% for Diesel+MWCNT150 (150 mg/lit MWCNT blended diesel) and KME+MWCNT150 (150 mg/lit MWCNT blended biodiesel) respectively. The hydrocarbon emission reduced by 23.07% and 27.58% for Diesel+MWCNT150 compared to neat diesel and KME+MWCNT150 compared to neat biodiesel respectively. There was also reduction in carbon monoxide emission with a reduction of 35.13% and 38.89% with Diesel+MWCNT150 as compared to neat diesel and KME+MWCNT150 as compared to pure biodiesel respectively at full load. There was slight increase in oxide of nitrogen and carbon dioxide emission with MWCNT blended diesel and biodiesel.**

***Key words* – Diesel engine, Karanja Methyl Ester, Multiwalled Carbon Nanotube, performance, Emission**

| **Nomenclature** | | | |
|---|---|---|---|
| KME | Karanja Methyl Ester (Karanja biodiesel) | Diesel+MWCNT50 | 1 Lit diesel + 50 mg MWCNT |
| MWCNT | Multiwalled Carbon Nanotube | Diesel+MWCNT100 | 1 Lit diesel + 100 mg MWCNT |
| HC | Hydrocarbon | Diesel+MWCNT150 | 1 Lit diesel + 150 mg MWCNT |
| CO | Carbon Monoxide | KME+MWCNT50 | 1 Lit KME + 50 mg MWCNT |
| $NO_X$ | Oxides of nitrogen | KME+MWCNT100 | 1 Lit KME + 100 mg MWCNT |
| $CO_2$ | Carbon dioxide | KME+MWCNT150 | 1 Lit KME + 150 mg MWCNT |
| BTE | Brake thermal efficiency | EGT | Exhaust gas temperature |
| BSFC | Brake specific fuel consumption | | |

## 1. INTRODUCTION

A diesel engine has an excellent reputation for its low fuel consumption, reliability and durability characteristics because of its higher brake thermal efficiency due to its high compression ratio and leaner fuel-air mixture. On the other hand diesel engine becomes the main air pollution source in the near future due to its combustion products. Polluted air leads to climate changes and affects plants, animals and human alike. Due to rapid growth of automobiles the demand for petroleum products raises day by day which is expected to rise to more than 240 million metric tonnes by 2021-22, which will further increase to around 465 million metric tonnes by 2031-32. However, the rapid depletion of petroleum products and the stringent regulations lay down by the government to engine manufacturers and consumers to follow the emission norms to save the environment from diesel engine pollution have triggered many researchers to identify renewable alternative fuels for diesel engine performance and good emission control [1]. In this regard, biodiesel derived from various vegetable oils such as karanja, jatropha, soybean, palm, neem oil etc. considered as potential alternative fuel for diesel engine.

The direct usage of vegetable oil in diesel engine is restricted because of their high viscosity, poor atomization, incomplete combustion and carbon deposition on the fuel injectors. The use vegetable oil in lower blend concentration with diesel results in engine performance and emission close to neat diesel, but with higher blend concentration performance and emission much inferior compare to neat diesel because of increase in viscosity [2, 3]. The viscosity of vegetable oil reduced by the process of transesterification by converting vegetable oil into methyl ester or ethyl ester known as biodiesel. The considerable work has been carried out by many researchers on performance and emission characteristics of diesel engine with biodiesel and its blends and showed significant improvement in engine performance and reduction in emission of CO, HC and smoke, but NOx emission was higher with biodiesel and its blends because of their higher oxygen content [4-7]. The recent advance in nanotechnology gives the way to produce energetic nanoparticles. The use of nanoparticles as additive will act as liquid fuel catalyst and there by enhance the combustion characteristics of engine which will improve engine performance and reduce emissions. H. tyagi et al. [8] conducted hot plate ignition probability taste to examine ignition properties of aluminium and aluminium oxide nanoparticles added diesel fuel and showed that addition of nanoparticles to fuel improve heat transfer properties and hence droplet ignited at much at much lower temperature than pure diesel Nanoparticles added fuel also shows shortened ignition delay, longer flame sustenance, rapid oxidation and hence complete combustion. The use of metal and metal oxide based nanoparticles as additive in fuel shows appreciable enhancement in thermal efficiency and reduced brake specific fuel consumption as well as level of harmful pollutants [9-16]. J. Sadhik Basha et al. [17] reported that use of carbon nanotube in jatropha methyl ester emulsion fuel significantly reduce peak cylinder pressure and heat release rate and because of microexplosion and secondary atomization phenomenon associated with CNT blended jatropha methyl ester increase brake thermal efficiency as well as reduced emission of HC, CO and $NO_X$. V. Selvan et al [18] studied performance and emission characteristics of VCR engine at optimum compression ration of 19:1 using diesterol (diesel-castor oil biodiesel – ethanol blend) - $CeO_2$ – CNT blends. They used $CeO_2$ and CNT of each 25, 50 and 100 ppm of concentrations added with diesterol blends. The addition of nanoparticles in diesterol blends increased thermal efficiency by 7.5%, reduced HC and smoke emission by 7.2% and 47.6% respectively compare to diesterol blends without nanoparticles.

The present experimental work is carried with the aim of evaluating performance and emission characteristics of single cylinder direct injection CI engine by using MWCNT as nanoadditive in diesel as well as karanja biodiesel.

## 2. FUEL PREPARATION AND ITS PROPERTIES

In present experiment, Multiwalled Carbon Nanotubes are blended with diesel and karanja biodiesel in three different proportions of 50mg/lit, 100 mg/lit and 150 mg/lit. Karanja biodiesel used in experiments was procured from SVM AGRO PROCESSOR, Nagpur, India and MWCNT was procured from Autus Nanolab Pvt. Ltd., Ahmedabad, India. Table 1 lists the details of MWCNT. For blending MWCNT in diesel taken a sample of diesel say l lit and then 50 mg of MWCNT is added in the diesel for making modified fuel of Diesel+MWCNT50. Consequently the dosage level of MWCNT increases to 100 mg/lit and 150 mg/lit for making Diesel+MWCNT100 and Diesel+MWCNT150 fuel respectively. Same procedure was adopted for making KME+MWCNT50, KME+MWCNT100 and KME+MWCNT150 fuel. After adding of MWCNT in the fuel it is shaken well and then it is placed on ultrasonic bath stabilizer (50 W, 33 kHz) for making stable and uniform suspension of Multiwalled Carbon Nanotube in the fuel. The ultrasonic bath stabilizer was provided by chemical department of Krantiguru Shyamajikrishna Verma Kachchh University, India. The properties of prepared fuel blends are represented in Table 2 and Table 3.

**Table 1 Details of MWCNT**

| Item | Specifications |
|---|---|
| Average particle diameter | 12-15 nm |
| Average length | 0.5-5 µm |
| No. of shells | 8-15 |
| Surface area | 231.85 $m^2/g$ |
| Purity | More than 97% |
| Appearance | Black powder |

**Fig 1 Photograph of MWCNT**

**Table 2 Properties of diesel and its blends with MWCNT**

| Properties | Diesel | Diesel+MWCNT50 | Diesel+MWCNT100 | Diesel+MWCNT150 |
|---|---|---|---|---|
| Calorific value (MJ/kg) | 45.8 | 45.89 | 45.95 | 45.99 |
| Kinematic viscosity @ 40 $^0$C (cSt) | 3.20 | 3.21 | 3.30 | 3.70 |
| Density @ 25 $^0$C (kg/$m^3$) | 810 | 813 | 814 | 820 |
| Sulphur content (ppm) | 50 | 50 | 50 | 50 |
| Flash point ($^0$C) | 76 | 66 | 61 | 58 |
| Water content (% w/v) | 0.06 | 0.06 | 0.06 | 0.06 |

**Table 3 Properties of Karanja biodiesel and its blends with MWCNT**

| Properties | KME | KME+MWCNT50 | KME+MWCNT100 | KME+MWCNT150 |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Calorific value (MJ/kg) | 36.60 | 36.71 | 36.87 | 36.96 |
| Kinematic viscosity @ 40 $^0$C (cSt) | 4.45 | 4.57 | 4.72 | 4.82 |
| Density @ 25 $^0$C (kg/m$^3$) | 865 | 875 | 877 | 880 |
| Sulphur content (ppm) | 12 | 12 | 12 | 12 |
| Flash point ($^0$C) | 168 | 162 | 157 | 154 |
| Water content (% w/v) | 0.01 | 0.01 | 0.01 | 0.01 |
| Cloud point ($^0$C) | -3 | -3 | -3 | -3 |
| Pour point ($^0$C) | -4 | -4 | -4 | -4 |

**Fig 2 Photograph of diesel and its blends with MWCNT**

**Fig 3 Photograph of karanja biodiesel and its blends with MWCNT**

## 3. EXPERIMETAL SETUP AND PROCEDURE

Experiments were performed on single cylinder air cooled compression ignition engine. Table 4 lists the engine specifications Figure 4 represents the schematic layout of experimental setup. All experiments were carried out at constant speed of 1500 rpm by varying the loads. The AC alternator was used as loading device. Fuel consumption measurement was carried out by volumetric method. The k-type thermocouple was used to measure exhaust gas temperature. The i3 sys make five gas analyzer was used to measure various constitute in the engine exhaust gases including HC, CO, $NO_X$ and $CO_2$. The engine was first started with neat diesel and warmed up. Then the fuel consumption, exhaust gas temperature and exhaust emission were measured. After that experiments were carried out using modified fuel blends.

**Table 4 Engine specifications**

| Parameter | Specification |
|---|---|
| Make | Powerlite |
| Rated brake power | 5.65 kW |
| Speed | 1500 rpm |
| No of Cylinder | 1 |
| Method of cooling | Air cooled |
| Bore × Stroke | 87.5 mm × 110 mm |
| Compression Ratio | 18:1 |

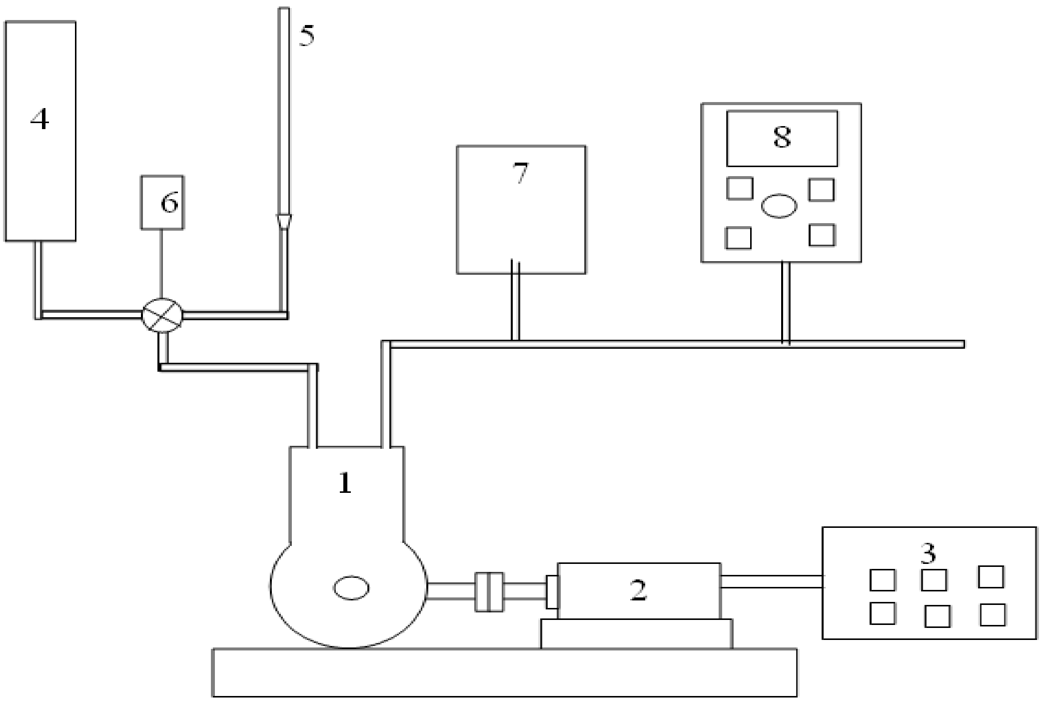


**Fig 4 Schematic layout of experimental setup**

| | | | |
|---|---|---|---|
| 1 | Diesel engine | 5 | Burette |
| 2 | AC Alternator | 6 | Fuel control valve |
| 3 | Load bank | 7 | Exhaust gas temperature indicator |
| 4 | Fuel tank | 8 | Exhaust gas analyzer |

## 4. RESULTS AND DISCUSSION

Experimentally observed data are used to calculate various performance characteristics of CI engine such as brake thermal efficiency, brake specific fuel consumption and exhaust gas temperature for all fuels considered in the experiment. All these performance and emission parameter include CO, HC, $NO_X$ and $CO_2$ are plotted against brake power for all fuel and compared.

*4.1 Variation in brake thermal efficiency*

The variation of brake thermal efficiency for the fuel considered in the test is shown in Figure 5. The brake thermal efficiency increases with increase in brake power for all fuels. As shown in Figure 5 the brake thermal efficiency using biodiesel was significantly lower compared to diesel. This could be due to lower heating value of biodiesel. It can be observed that addition of MWCNT in diesel and biodiesel increase the brake thermal efficiency compared to diesel and biodiesel without MWCNT. The nanoparticles added in the fuel causes microexplosion of fuel droplet which improves air fuel mixing and accelerate combustion results in increase the brake thermal efficiency using nanoparticle blended fuel [19]. As seen in Figure 5, the brake thermal efficiency also increases with increase in concentration of MWCNT in the fuel. At full load the brake thermal efficiency was increase by 1.20%, 2.18% and 3.79% with Diesel+MWCNT50, Diesel+MWCNT100, Diesel+MWCNT150 compared to pure diesel and 1.90%, 3.34%, 4.18% with KME+MWCNT50, KME+MWCNT100 and KME+MWCNT150 compared to biodiesel without MWCNT.

*4.2 Variation in brake specific fuel consumption*

Brake specific fuel consumption (BSFC) is a measure of fuel consumption per unit brake power. As shown in Figure 6, the BSFC decrease with increase in engine power for all fuels. Further, the BSFC value was lower for biodiesel compared to diesel duel lower heating value of biodiesel. The improvement in brake thermal efficiency with MWCNT blended diesel and biodiesel is the direct indication of lower BSFC value for MWCNT added diesel and biodiesel compared to fuel without MWCNT. At full load BSFC values for diesel and biodiesel were 0.270 and 0.422 kg/kWh respectively, where as it was 0.389, 0.366, 0.354, 0.259, 0.250 and 0.238 kg/kWh with Diesel+MWCNT50, Diesel+MWCNT100, Diesel+MWCNT150, KME+MWCNT50, KME+MWCNT100 and KME+MWCNT150 respectively. Hence BSFC was reduced by 4.07%, 7.41%, 11.85% with Diesel+MWCNT50, Diesel+MWCNT100, Diesel+MWCNT150 compared to neat diesel respectively and 7.81%, 13.27%, 16.11% with KME+MWCNT50, KME+MWCNT100 and KME+MWCNT150 respectively compared to pure biodiesel.

*4.3 Variation in exhaust gas temperature*

Figure 7 represents the variation in exhaust gas temperature for the fuel considered in the experiment. As shown in Figure 7 the exhaust gas temperature increases with increase in brake power for all fuels because of increase in quantity of fuel burnt with increase in load. It could be observe that addition of MWCNT in diesel and biodiesel increase the exhaust gas temperature compare to diesel and biodiesel without MWCNT. The addition nanoparticles in the fuel causes higher heat release rate and accelerate combustion leading to increase exhaust gas temperature. At full load the EGT value for diesel and biodiesel were 345 and 304$^0$C respectively, where as it was 358, 386, 398, 311,324 and 332$^0$C for Diesel+MWCNT50, Diesel+MWCNT100, Diesel+MWCNT150, KME+MWCNT50, KME+MWCNT100 and KME+MWCNT150 respectively.

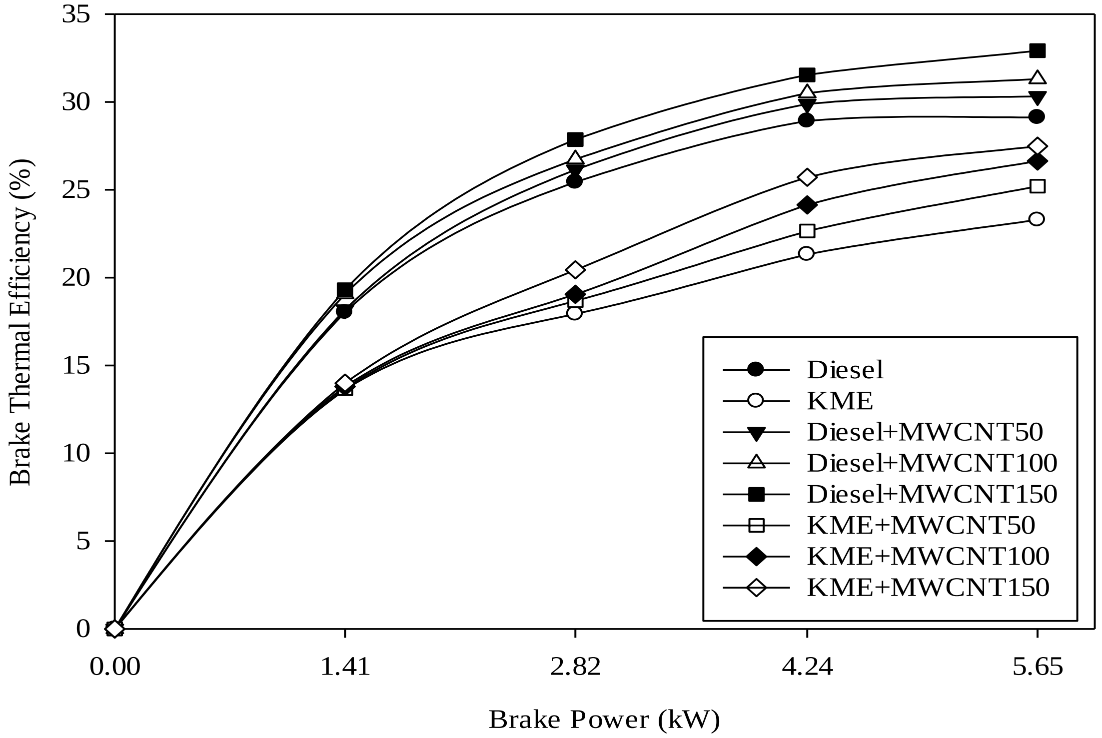


**Fig 5 Variation in brake thermal efficiency with brake power**

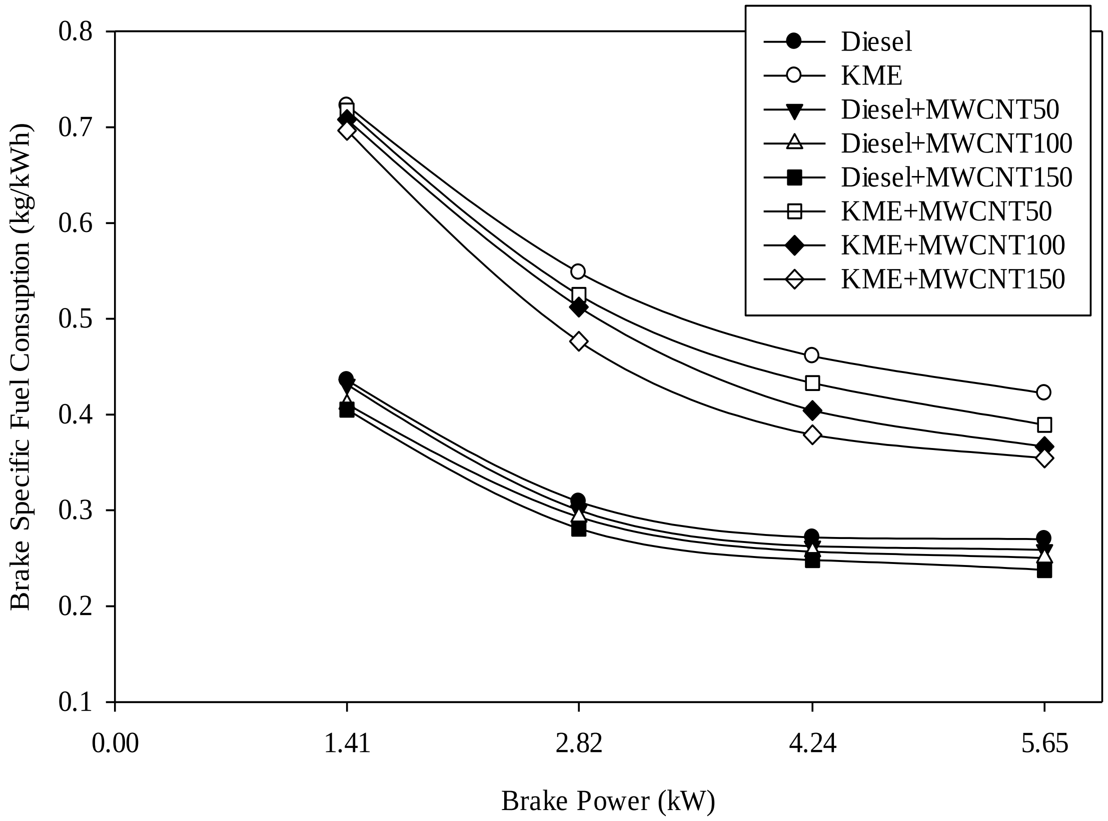


**Fig 6 Variation in brake specific fuel consumption with brake power**

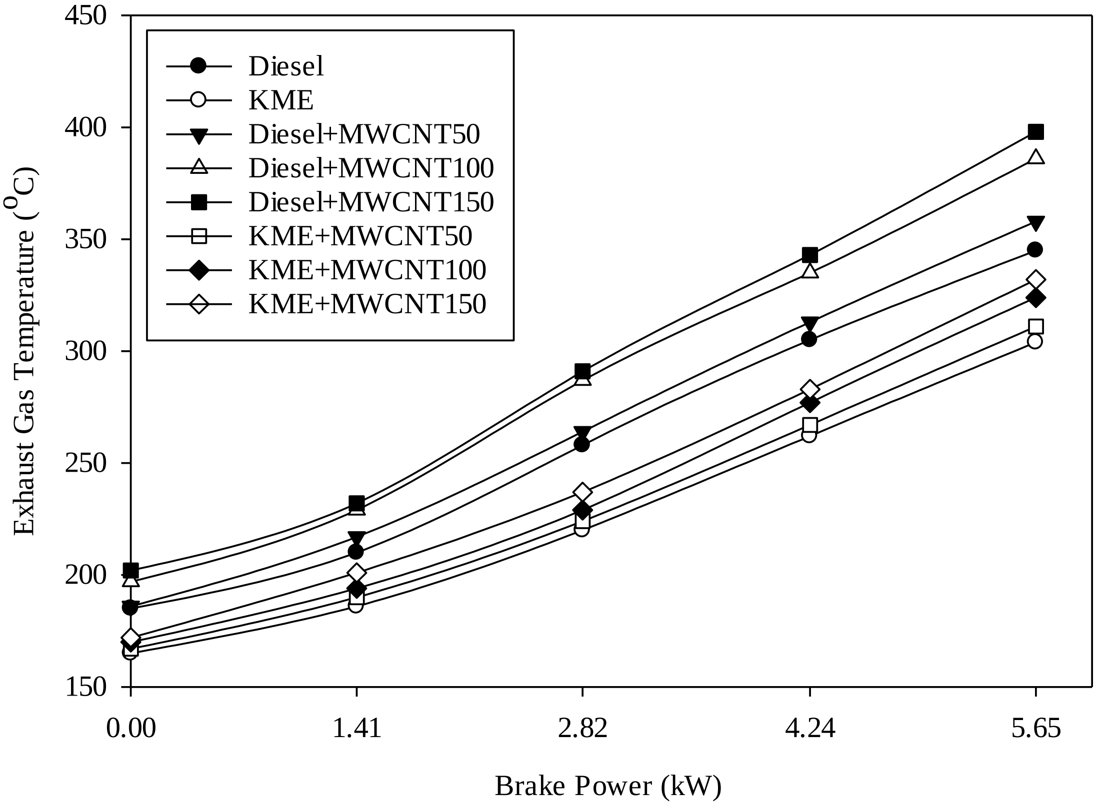


**Fig 7 Variation in exhaust gas temperature with brake power**

*4.4 Variation of carbon monoxide (CO) emission*

Figure 8 shows the variation in carbon monoxide (CO) emission with engine brake power. The carbon monoxide emission from the engine is indirect indication of incomplete combustion of fuel caused by poor mixing of air-fuel and lack of temperature. As shown in Figure 8 the CO emission decreases with increase in engine brake power. This could be due to increase in temperature with increase in engine brake power. Because of higher oxygen content of biodiesel, the CO emission was significantly reduced with biodiesel compare to neat diesel for all loads as seen in Figure 8. There was further reduction in carbon monoxide emission with the addition MWCNT in the diesel and biodiesel. At lower brake power, there was no significant difference in fuel consumption among the tested fuels as observed from the performance characteristics. Hence there was no significant difference in CO emission among the tested fuel. With increasing the concentration of MWCNT in diesel and biodiesel the CO emission decreases for all fuel blends. The addition of nanoparticles in base fuel improve the atomization of fuel which enhances air fuel mixing and burning rate gives more complete combustion and hence reduce CO emission [14,17]. The higher reduction in CO emission was observed at full load with nanoparticles blended diesel and biodiesel compared to pure diesel and biodiesel. At full load the CO emission were 0.037% and 0.018% for diesel and biodiesel respectively, where as it was 0.034%, 0.028%, 0.024%, 0.015%, 0.012% and 0.010% with Diesel+MWCNT50, Diesel+MWCNT100, Diesel+MWCNT150, KME+MWCNT50, KME+MWCNT100 and KME+MWCNT150 respectively. Hence at full load CO emission reduced by 8.10%, 24.32%, 35.13% with Diesel+MWCNT50, Diesel+MWCNT100, Diesel+MWCNT150 respectively compared to neat diesel and 16.67%, 33.33%, 38.89% with KME+MWCNT50, KME+MWCNT100, KME+MWCNT150 respectively compared to biodiesel.

*4.5 Variation of hydrocarbon (HC) emission*

The variation of hydrocarbon (HC) emission is represented in Figure 9. The hydrocarbon emission from the engine is direct indication of incomplete combustion of fuel. The hydrocarbon emission for biodiesel was lower for all brake power compare to pure diesel because of higher oxygen content of biodiesel. The addition of MWCNT in diesel and biodiesel results in reduction in HC emission as seen in Figure 9. The MWCNT nanoparticles added to the fuel improve the combustion which reduces HC emission. At lower load, there was no significant difference in HC emission among the test fuels because of lower fuel consumption rate at lower load. Also it is seen from the Figure 9 that the HC emission decreases with increasing dosing level of MWCNT nanoparticles. At full load HC emission for diesel and biodiesel were 52 and 29 ppm respectively, where as it was 50, 46, 40, 26, 23 and 21 ppm for Diesel+MWCNT50, Diesel+MWCNT100, Diesel+MWCNT150, KME+MWCNT50, KME+MWCNT100 and KME+MWCNT150 respectively. Hence at full load HC emission was reduced by 3.85%, 13.46%, 23.07% with Diesel+MWCNT50, Diesel+MWCNT100, Diesel+MWCNT150 respectively compared to diesel and 10.34%, 20.69%, 27.58% with KME+MWCNT50, KME+MWCNT100 and KME+MWCNT150 respectively compared to pure biodiesel.

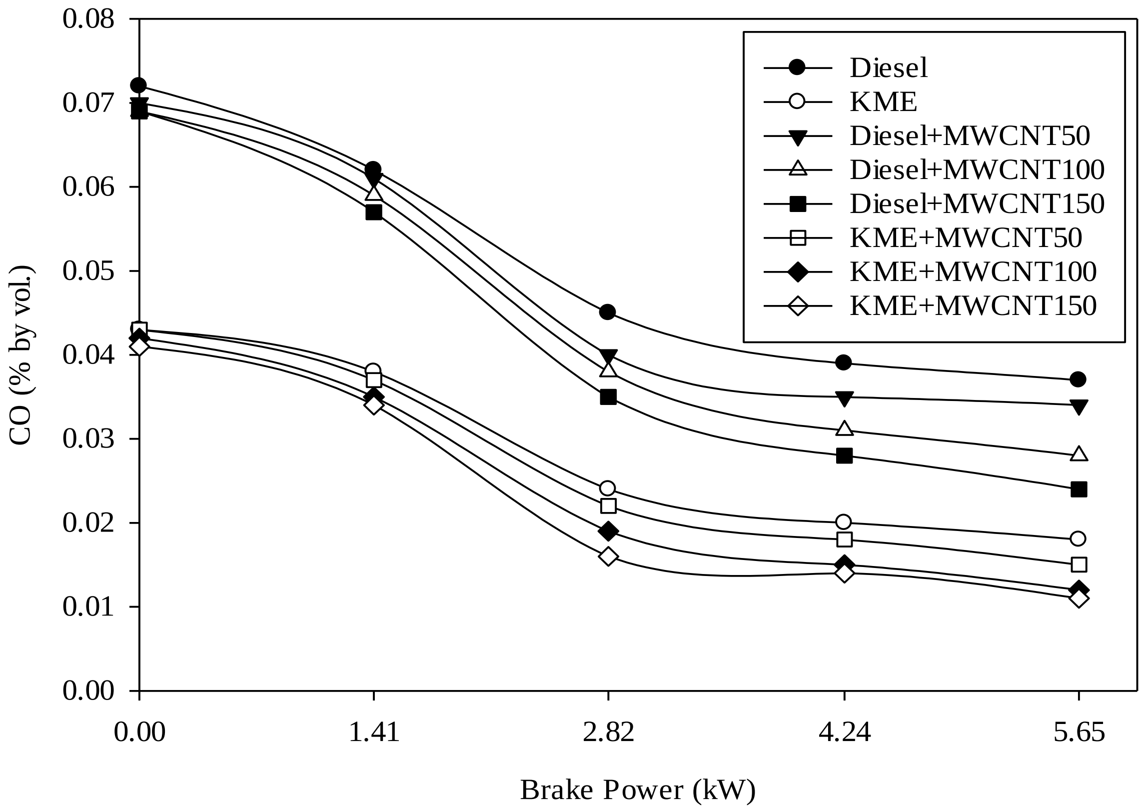


**Fig 8 Variation of carbon monoxide (CO) emission with brake power**

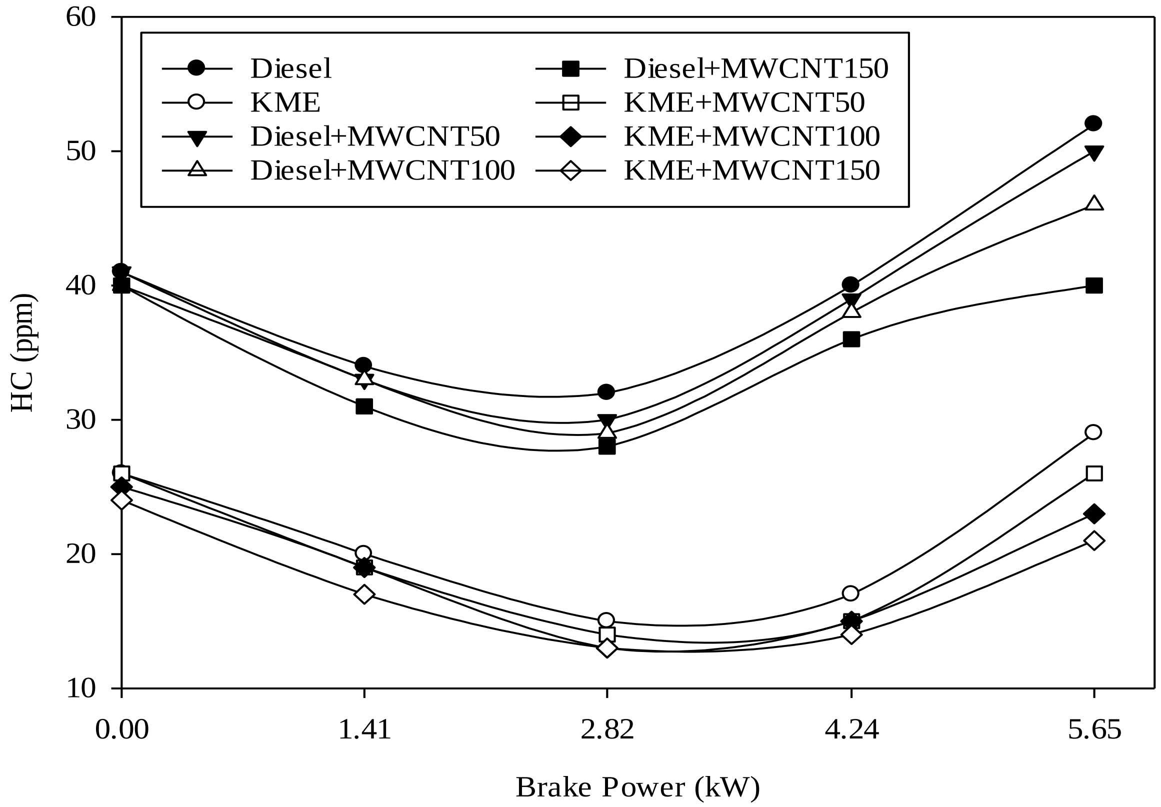


**Fig 9 Variation of hydrocarbon (HC) emission with brake power**

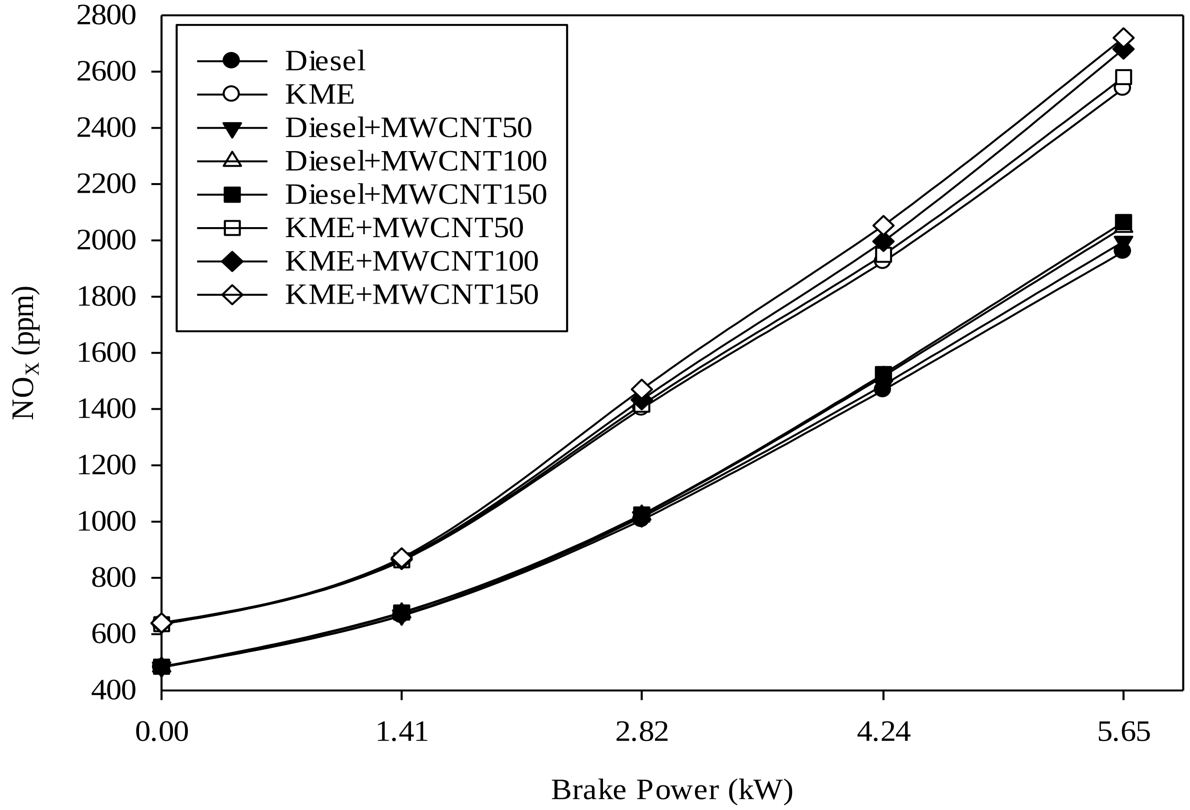


**Fig 10 Variation of oxide of nitrogen ($NO_X$) emission with brake power**

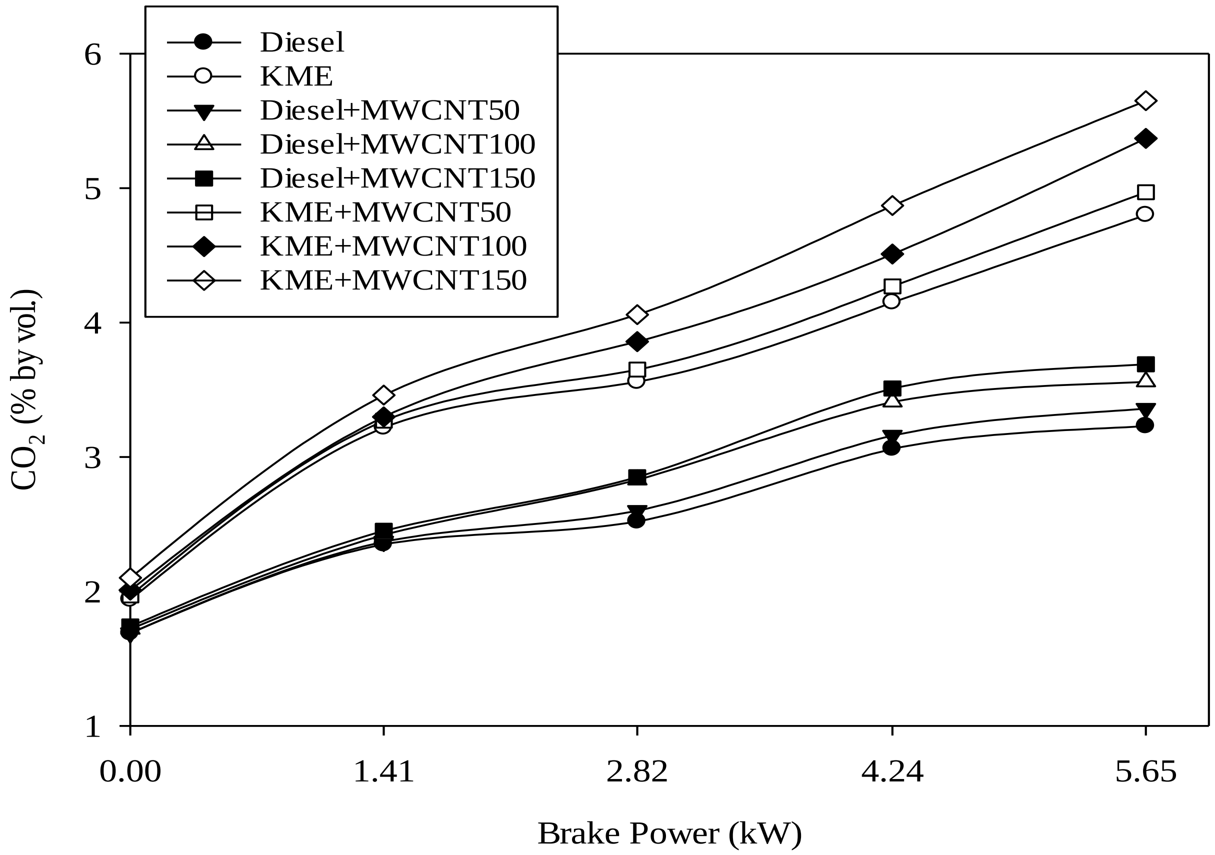


**Fig 11 Variation of carbon dioxide ($CO_2$) emission with brake power**

### *4.6 Variation of oxides of nitrogen ($NO_X$) emission*

Apart from CO and HC emission, the third main pollutant is oxides of nitrogen. Figure 10 shows variation in $NO_x$ emission for diesel, biodiesel and MWCNT blended fuel. It can be observed that the emission of $NO_x$ was increases with increase in brake power for all fuels. The addition MWCNT in diesel and biodiesel increase $NO_X$ emission as shown in Figure 10 because of increase in exhaust gas temperature by addition of MWCNT in fuel as seen in Figure 7. At full load, the $NO_x$ emission for diesel and biodiesel were 1960 and 2540 ppm respectively, where it was 1996, 2047, 2065, 2580, 2680 and 2720 ppm for Diesel+MWCNT50, Diesel+MWCNT100, Diesel+MWCNT150, KME+MWCNT50, KME+MWCNT100 and KME+MWCNT150 respectively. Hence at full load $NO_X$ emission increased by 1.84%, 4.44%, 5.36% with Diesel+MWCNT50, Diesel+MWCNT100, Diesel+MWCNT150 compared to diesel respectively and 1.57%, 5.51%, 7.09% with KME+MWCNT50, KME+MWCNT100, KME+MWCNT150 respectively compared to pure biodiesel.

### *4.7 Variation of carbon dioxide ($CO_2$) emission*

Figure 11 shows the variation in carbon dioxide ($CO_2$) emission with engine brake power for the fuel considered in the test. As shown in Figure 11, with increase in brake power carbon dioxide emission increases for all fuels. The MWCNT added fuel shows increase in $CO_2$ emission compared to base fuel. This could be due to improved combustion and mixing of air-fuel by addition of nanoparticles in the base fuel. At full load $CO_2$ emission for diesel and biodiesel were 3.23% and 4.8% respectively, where as it was 3.36%, 3.56%, 3.69%, 4.97%, 5.37% and 5.65% with Diesel+MWCNT50, Diesel+MWCNT100, Diesel+MWCNT150, KME+MWCNT50, KME+MWCNT100 and KME+MWCNT150 respectively.

## 5. CONCLUSIONS

The performance and emission characteristics of single cylinder diesel engine under various concentration of MWCNT in diesel and karanja biodiesel were investigated to establish the effect of MWCNT as nanoadditive in diesel and karanja biodiesel. Based on experimental results following conclusions are derived:

1. There was significant improvement in brake thermal efficiency and reduction in brake specific fuel consumption by using MWCNT as nanoadditive in diesel and biodiesel compared to diesel and biodiesel without MWCNT. At full load, the brake thermal efficiency was increased by 1.20%, 2.18% and 3.79% with Diesel+MWCNT50, Diesel+MWCNT100, Diesel+MWCNT150 compared to pure diesel and 1.90%, 3.34%, 4.18% with KME+MWCNT50, KME+MWCNT100 and KME+MWCNT150 compared to biodiesel without MWCNT. The brake specific fuel consumption reduced by 11.85% and 16.11% with Diesel+MWCNT150 compared to neat diesel and KME+MWCNT150 compared to pure biodiesel respectively at full load.
2. The addition of nanoparticles in the fuel improve the atomization of fuel which enhance air fuel mixing and burning rate and hence gives more complete combustion. Hence there was significant reduction in HC and CO emission by using MWCNT added diesel and biodiesel. At full load, CO emission reduced by 8.10%, 24.32%, 35.13% with Diesel+MWCNT50, Diesel+MWCNT100, Diesel+MWCNT150 respectively compared to neat diesel and 16.67%, 33.33%, 38.89% with KME+MWCNT50, KME+MWCNT100, KME+MWCNT150 respectively compared to biodiesel, where as HC emission reduced by 3.85%, 13.46%, 23.07% with Diesel+MWCNT50, Diesel+MWCNT100, Diesel+MWCNT150 respectively compared to diesel and 10.34%, 20.69%, 27.58% with KME+MWCNT50, KME+MWCNT100 and KME+MWCNT150 respectively compared to pure biodiesel.
3. The addition of nanoparticles in the fuel causes higher heat release rate and accelerate combustion leading to increase exhaust gas temperature. Hence, MWCNT added fuel shows slight increase in NOx emission compared to fuel without MWCNT. Because of improved combustion, the $CO_2$ emission also increases with MWCNT blended fuel.

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