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Experimental And Emission Analysis Over New Urea – SCR Array For CI Engine Fueled With Mahua Oil Methyl-Ester

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Abstract

A new unit of emission-aftertreatment setup developed with DPF, TWC-converter having novel DEF-unit by manual control, for improving the ability of present Urea - SCR arrangement. CIE powered through neat mahua oil methyl-ester (MOME) and contrasted by pure-Diesel. Output indicates ~99% reduction in both CO and HC by new arrangement, simultaneously noticed less amount of NOx present, when judged with usual setup.

Keywords: Emission control, Device performance, DPF, DEF, CIE, TWC, MOME.

1. Introduction

To ensure compliance with the requirements of the guidelines, emission-after-treatment array practice is used for CI Engines. Europe road demonstrations of the $(NH_2)_2CO$-SCR array are performed in realistic way. But, there are still problems to solve in case of practical implementation of $(NH_2)_2CO$-SCR systems. 1st less instigation of NOx mitigation with NH_3 slide under transient, low exhaust heat situations experienced through real functioning environments.

In particular, NH_3-liquid evaporation should be factored into attention. To enhance the exterior - reaction and gaseous – state - reaction, current research is carried out with vaporization by fresh variety DEF-feeding set by manual control. Flowing line (copper-tube) enfolded around emission-pipe to raise the DEF-temperature.

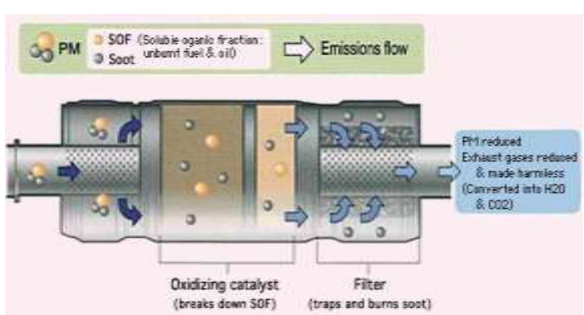
The earth is currently captivating biological crumble and not-renewable oils crisis. Number of assessments implemented for discovering substitute for not-renewable oils. Flaming of bio-oils in the CIE reduces the diverse toxins in exhaust. Hence, via applying bio-oils in current CIE will develop the environmental significance by fall in the quantity of GHGs.

1.1 Testing fuels

The sapotaceae family includes Madhuca longifolia in its kinship. It's a wet plant from India obtainable just about northern part. It grows 20m tall and farms at quick pace. Mahua oil, which can be seen as a potential rival for alternative fuel, is thus convenient in excess. Additionally, by modernizing the utilization of Mahua-oil as substitute fuel, home and nation undeveloped monetary organization will be strengthened. Characteristics of testing oil are shown in Table1. From Table1, it is clear that particularly, the noteworthy boost in the fire-point illustrates the volatility of the MOME. Additionally, it has been shown that biodiesel's flash and fire points rise. Therefore, the bio diesel fuel is extremely simple to hoard and protected for carrying as contrasted with neat-diesel. As the proportion of bio-diesel in the mixture increases, the gross calorific value decreases. Table1 also showed a rising trend in cetane number.

Table.1 Characteristics of testing fuels

PROPERTIES	DIESEL-OIL	MAHUA OIL METHYL ESTER (MOME)
Gross Calorific Value (MJ/kg)	45.59	41.82
Flash point in ^{0}C	65	170
Fire point in ^{0}C	70	183
Kinematic viscosity at 40°C (cSt)	2.6	6.04
Specific gravity	0.82	0.88
Cetane number	46	52



1.2 DPF

This structure enfolds commonly Al_2O_3 wash-coat over honeycomb outline pottery piece as discovered in Figure1.

Fig.1DPF

1.3 TWC

The below configuration acquires its heading because of controlling 3 principal contaminants of exhaust viz., NOx, VOC's & CO. The structure usually grasps Al_2O_3 wash- wrap on honey-comb contour ceramic chunk as portrayed in Figure2. Costliest substances were coated on Al_2O_3. Active segment of substance is moreover alienated as oxidation & reduction parts. Amalgamations of platinum-rhodium constituents execute dynamic actions to do well reduction, while platinum-palladium executes dynamic ingredients for oxidation.

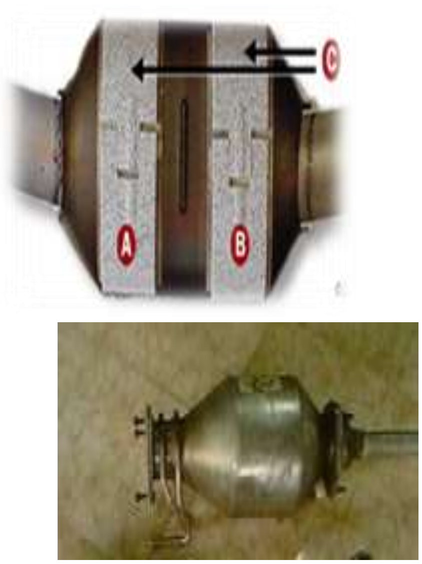


Fig. 2 TWC

A: Reduction Catalyst

B: Oxidation Catalyst

C: Honeycomb Ceramic Structure

Reduction of nitrogen oxides:

$2NO_x \rightarrow xO_2 + N_2$

Oxidation of carbon monoxide:

$2CO + O_2 \rightarrow 2CO_2$

Oxidation of unburnt hydrocarbons (HC):

$C_xH_{2x+2} + [(3x+1)/2]O_2 \rightarrow xCO_2 + (x+1)H_2O$

1.4 DEF

DEF is an inorganic mixture made up of 67.5% water and 32.5 percent granulated $(NH_2)_2CO$. DEF serves as a delivery route for NH_3, which is necessary for converting NOx from exhaust to N_2, H_2O, and CO_2.Urea decay response (Water evaporates and urea thermally degrades to create NH_3 and CO_2 as DEF has been embedded by the heated stream of exhaust fumes).

$(NH_2)_2CO \rightarrow NH_3 + HNCO$ further reaction $HNCO + H_2O \rightarrow CO_2 + NH_3$

Overall reaction for Urea Decomposition

$(NH_2)_2CO + H_2O \rightarrow 2\ NH_3 + CO_2$

Ammonia Reaction (with oxygen and a catalyst)

$4\ NH_3 + 4\ NO + O_2 \rightarrow 4\ N_2 + 6\ H_2O$ or $8\ NH_3 + 6\ NO_2 + O_2 \rightarrow 7\ N_2 + 12\ H_2O$

2. Literature Survey

According to Resitoglu [1], PM, NOx, HC, and CO are the main contaminants created in biodiesel-powered CIEs. NOx makes up 50% of these impurities, with PM coming in second.

Hoekman et al. [1-2] conducted research on biodiesel and the mixtures that CIE uses. Lot of assessors established to contaminants CO, HC and PM notably reduced while NOx experiential elevation.

Sindhu [3] investigated that crack injection; a small amount of fuel is taken hold of in the early pulse that threatens to minimize NOx suitable for pre-mix flaring. Divided injections are used so that NOx can be reduced. During modern ages, SCR has been demonstrated to be an effective after-treatment method for reducing NOx, yet if it is momentary in current producer demands exhaust modifications those are not inexpensive. LTC tactic's be employed through modern CIE to decline NOx & PM by Praveena [4].

Yuvarajan et al. [5-7] trial tested bio-oildiesel & their varied mixes used for CIE directs toward go up in NOx & BSFC compared to neat diesel disturbed to superior O_2 % in mixes.

Fairly, bio-diesel oils declares go down in dangerous poisons such as PM, CO, & HC; in opposition, it generates more NOx demonstrated by Janaun et al. [8-9] The key hazardous NOx affects nearby environs through acidic-rains, person sickness, etc. Additionally, the topic of CO and NOx being the main poisons in the formation of troposphere-O_3 is investigated by Latha et al. [10–11].

Bio-dieseloil having 60% - 65% of H_2O mix by fuel can reduce up to 50% NOx, extra WI (H_2O-injection) % able of reduce additional NOx in dissimilar load situations recognized by Tauzia [12].

Hountalas [13] concentrated on the utilization of WI and H_2O-suspension in DI-CIE as two techniques for NOx reduction operations. Outcomes exposed that, H_2O-injection is better judged against to H_2O-blend; equally, above 2 practices were proficient as compared to normal CIE job.

Furthermore, Sahin [14] determined emulsification method lead to lift in HC & CO owing to reduce during flaming hole heat that is later manipulate firing capability. Basha [15] examined the function of nanoadditives in CIE-emulsified biodiesel oil. worked with emulsified bio-diesel made of 83% Jatropha bio-diesel, 15% water, and 2% surfactant. Based on trailing with a 1-bore engine, it was estimated that NOx decreased by 21%, PM decreased by 15%, but that HC increased by 46%, BTE improved by 2.5%, and BSFC decreased by 2.6%.

Some examiners Swaminathan et al. [16-17] realizes synchronized styles toward obtaining superior results like fuel-additives plus EGR & ITR plus EGR.

Associated to earlier circumstances, Saravanan [18] investigated the combined impact of EGR, ITR, and injection-pressure on a 1-bore CIE powered by RME biodiesel. Output is least combination of engine-parameters via utilization of Taguchi- procedure reduces figure of practical attempt & instituted NOx go down by light compensation on the usefulness and other pollutions.

Document reviewed on NOx reducing methods like WI, H_2O-emulsification, injection-timing retardation & coexisting tools & its control over dissimilar operational features deliberated within bio-oil-CIE by Prabhu Appavu [19].

Theoretical replica of Urea feeding unit-denoxtronic3.1 produced by Bosch [20] has been in sequence making at many OEMs while middle 2008. Applying of denoxtronic3.1 before eases completion through Euro6 & Tier-2 Bin-5 limitations & is treated standard for the majority of the current effort in this subject. Probable claims: The denoxtronic3.1 is chiefly intended for use in commuter cars and in the light-duty division. Moreover feasible executions were there in off - highway sector for engines in span of 56kW ---100kW.

Prabhu L [21] examined various parameters of a 1-bore-engine utilizing TiO_2 nano-elements like stabilizer in dieseloil & dieseloil-biodieseloil mixes. A 250ppm of TiO_2 nano-elements are mixed with 20% biodieseloil-dieseloil mix (B20). Those mixes were processed toward speedier mixing chased via ultrasonic tub stabilization which advances constancy of mixtures. Trials performed on a CIE to find parameters by dieseloil, 250ppm TiO_2 with B20 biodiesel mix by dissimilar loads. For 250ppm nanoparticle applied with B20 mixtures at 100%load, the output resulted in an increase in BTE and a reduction in BSFC of 12%. CO, HC, and smoke emissions decrease as NO% marginally increases as a result of the chamber's climax burning heat.

Mahua oil biodiesel was researched by A. Mahalingam et al. [22] to examine the properties of its emissions when blended with various amounts of octanol in stationary diesel engines. Biodiesel made from mahua oil is made using traditional transesterification. This study found that adding octanol in various amounts significantly reduced all of the emissions linked to mahua oil biodiesel.

Mahua oil, which is combined with diesel, is the source of biodiesel according to research by Prabhakar S et al.,[23]. To validate the program created for the performance characteristics of a biodiesel fuelled engine, performance characteristics of biodiesel are compared with those of diesel.

According to M. Haridass & M. Jayaraman [24], the issue with biodiesel is the increased emission of nitrogen oxides (NOx). Ad-Blue (urea) solution can be used to reduce NOx emissions. In this study, an experimental investigation was conducted to determine whether the selective catalytic reduction (SCR) approach was appropriate for lowering NOx. Property characterization has been done for a variety of mixes to get accurate findings. When the engine was run on 25% biodiesel, it was discovered that NOx levels significantly decreased (by about 3.91%), saving 25% on diesel. This study proves that using the SCR technology with a 25% biodiesel addition is a practical option that doesn't need changing the engine or sacrificing engine performance.

A thorough examination of the urea-water spray wall impingement and its effects on the dispersion of the reducing agent and the formation of deposits, as well as the performance of the system, is provided by Yujun Liao et al. in their study [25]. The impingement process can be seen in great detail in high speed photos. Under normal diesel exhaust flow conditions, impinging spray mass flux distribution and droplet size distribution have also been measured. A commercial 3-Hole pressure-driven injector dosing into a flow channel was used to complete the task.

An investigation on the effects of nano-additives on the operation and emission characteristics of a diesel engine powered by blended biodiesel and fitted with a urea-SCR system is presented by Mina Mehregan and Mohammad Moghiman [26]. The base fuel used in this investigation was B20 blended biodiesel, which was composed of 80% diesel and 20% biodiesel made from used frying oil. In this investigation, nano-fuel additives with mass fractions of 25 and 50 ppm of manganese oxide and cobalt oxide were utilized. According to the testing findings, the NOx and CO emission were noticeably reduced when compared to base fuel, while the brake specific fuel consumption and brake thermal efficiency of nanoparticles mixed gasoline were both significantly improved.

The performance analysis of a urea-water selective catalytic reduction system for decreasing exhaust emissions from a direct-injection, water-cooled diesel engine is the focus of C. Solaimuthu and P. Govindarajan [27]. Mahua (madhuca indica) bio diesel (methyl ester of mahua oil) and its blend with diesel in various volumetric proportions have been studied for their effects on engine performance, combustion, and emissions. The various fuel blends' thermo-physical characteristics have been measured and presented. From no load to full load, the experiment has been run in steady state throughout. According to the test results, the emission characteristics of HC and NOx tend to decrease when a selective catalytic reduction approach is applied. According to research, the B25 produces the lowest HC and NOx emissions at full load, with percentage reductions of 5.88 and 1.18%, respectively, when compared to the B0.

Performance and emission characteristics were studied by Vibhanshu, V et al. [28] using 10, 20, and 100% blends of diesel. CO emissions were 38% lower and NOx emissions 21% higher than those of neat diesel at full load, respectively. HC emission for pure mahua biodiesel was 42 ppm, compared to 58 ppm for diesel fuel. All mahua oil methyl ester mixes had less smoke capacity than mineral diesel. All blends of mahua oil methyl ester exhibit ignition lag, according to the combustion outcome. D100 has an ignition delay of 10.5°, whereas neat mahua oil methyl ester has an ignition delay of 7°. However, the ignition delay for the M10 and M20 engines varied by 7.3° and 8°, respectively. Overall, it can be said that biodiesel made from mahua oil can easily replace up to 20% (v/v) of diesel and may be used in a 1-bore CIE without modification.

Mahua oil that has not been treated is currently being transesterified to become MOME. Retrofit DPF+TWC+DEF array installed in CIE outflow pipe. The fuel tank was filled with diesel oil with a DPF+TWC+DEF unit, a DPF+TWC unit, and without a DPF+TWC+DEF array in order to obtain the necessary recordings. The engine was then ran with MOME using the various collections of DPF+TWC+DEF stated above. DPF+TWC+DEF, DPF+TWC, and without DPF+TWC+DEF arrays are used to achieve the performance and emission

parameters of dieseloil and MOME, and these results are contrasted.

3. Particulars of Testing

3.1 Engine setup

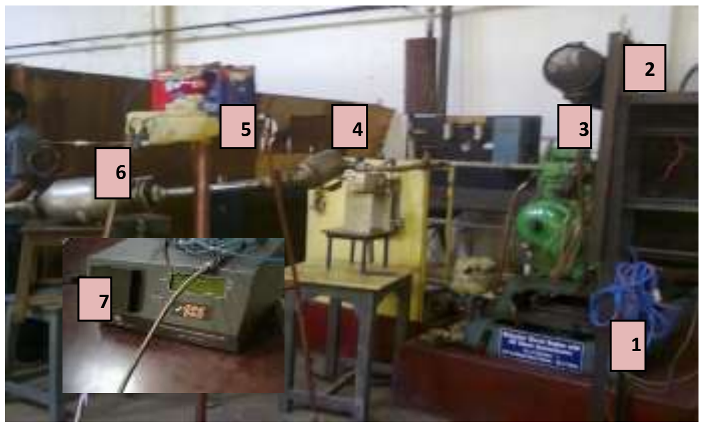


Fig. 3 Experimental Setup

3.2 Major components (represented in the above Fig. 3)

1. kirloskar-CIE
2. fuel tank
3. power board
4. DPF
5. DEF tank with supply module & battery
6. TWC
7. Multiple-gas analyzer

3.2 Test rig details

- ❑ Engine Manufacturer : KIRLOSKAR (DC Shunt Dynamometer)
- ❑ Type : 1-cyl 4-stroke DI CI engine
- ❑ Aspiration : Naturally Aspirated
- ❑ Bore : 80 mm
- ❑ Stroke : 110 mm
- ❑ Rated Speed : 1500 rpm
- ❑ Cooling System : Water Cooled

- Rated Power : 5BHP/ 3.7 KW

3.3 Novel DEF arrangement:

Name of the essence	Aqueous urea (Ad-Blue) solution
Chemical formula	$(NH_2)_2$ $CO.H_2O$
Composition	30% of urea and 70% of water
Dosing quantity	162g/h @ 1.5bar
Nozzle category, matter & diameter	1- Hole, Brass & 400 µm
Ecological functioning conditions	
Delivery system :	-30…..70^{0}C
Feeding set :	-30…..140^{0}C
Working electrical energy	12 V
Delivery pipe extent linking supply & dosing systems	3805 mm
Delivery pipe substance, shape	Cu, Circular tube
DEF- container matter	Plastic

4. Outputs

4.1 Performance Parameters:

Performance tests executed while CIE fuelled via MOME and Diesel independently, under variety of loadings from zero to 2kW. Performance is evaluated in terms of BP, BTHE, ME, and VE. The findings obtained for the DPF+TWC+DEF array linked at the drain pipe's end channel are distinguished from those obtained without joining any of the aforementioned sets and with the DPF+TWC set.

4.1.1 Brake Power (BP)

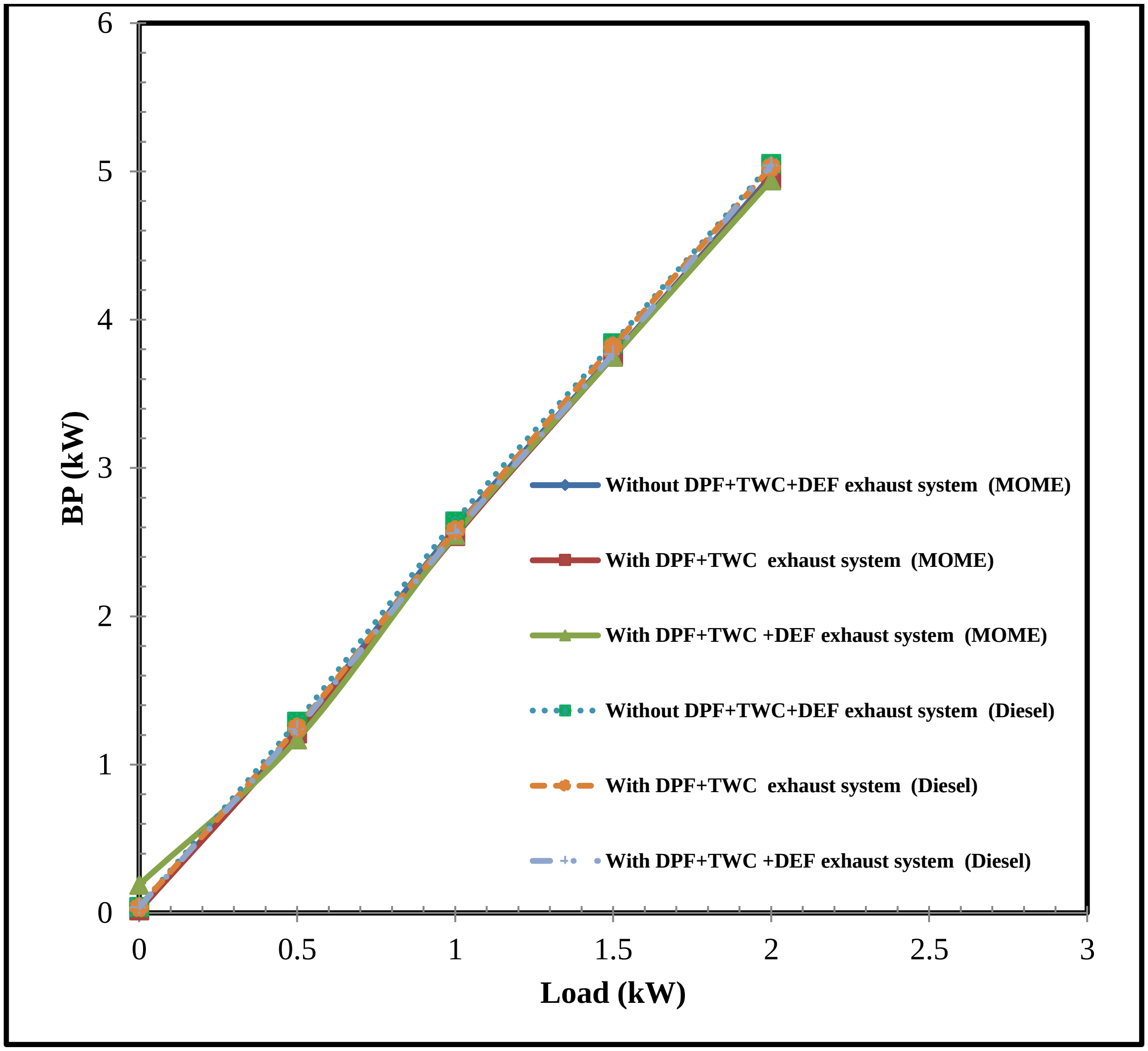


Fig. 4.1 Load vs BP

With three distinct setups, Figure 4.1 explains brake power for MOME and diesel individually. As may be seen, the BP for MOME is trending in the same direction as Diesel while somewhat declining. Due to back pressure, it may be observed that almost all loads do not affect the BP in any way when the DPF+TWC+DEF array is linked in the exhaust conduit.

4.1.2 Brake Thermal Efficiency (BTHE)

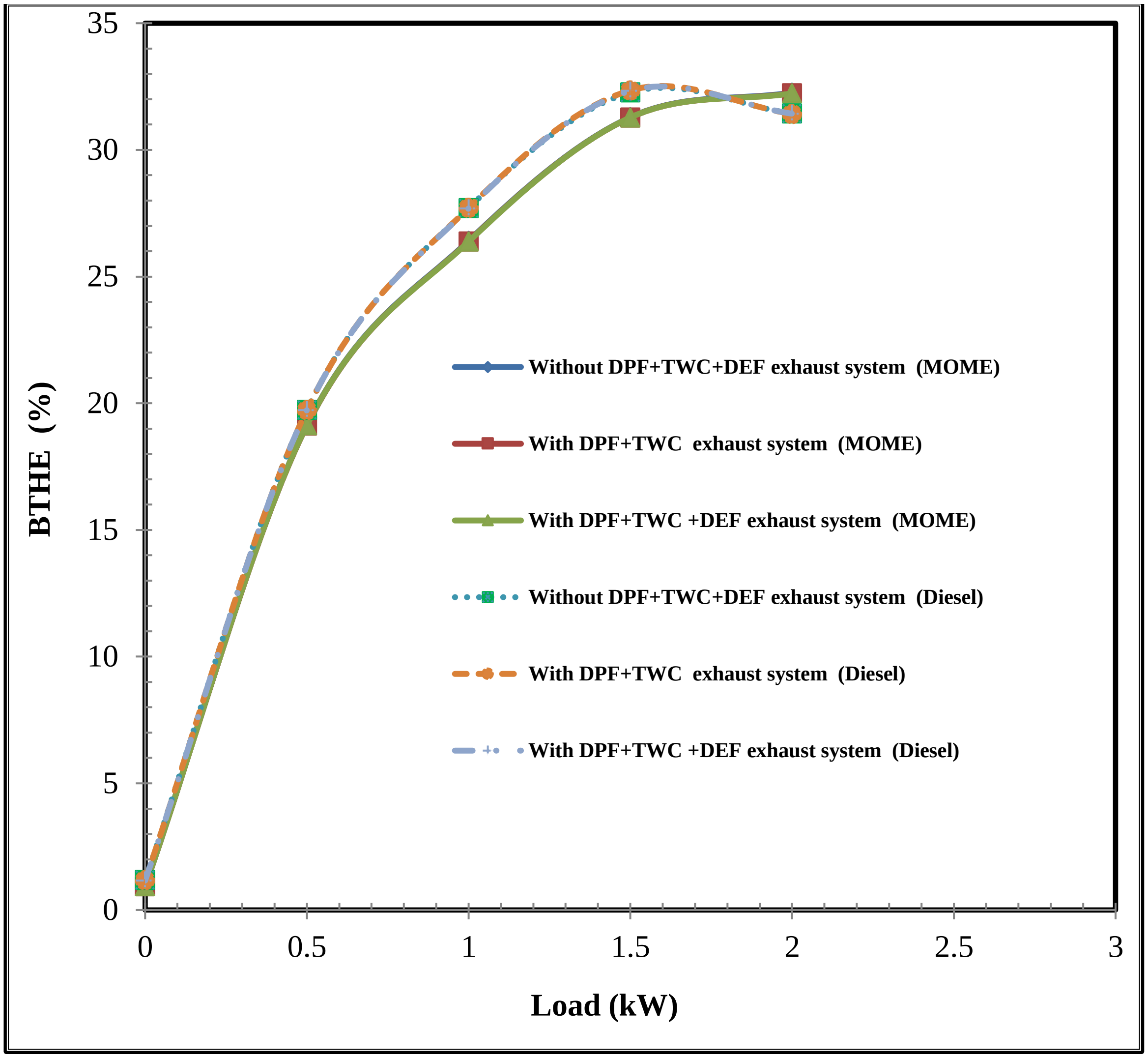


Fig. 4.2 Load vs BTHE

The deviation of BTHE based on load for three distinct layouts is shown in Figure 4.2. As expected, back pressure prevents adding converter sets resembling BP to the exhaust channel from having any effect on BTHE. At greater loads, the efficiency varies significantly, as can be seen. This is due to the fact that no engine working factor adjustment has been done for biodiesel function. Additionally, due to MOME characteristics, BTHE declines significantly at 1kW and 2kW loads.

4.1.3 Mechanical Efficiency (ME)

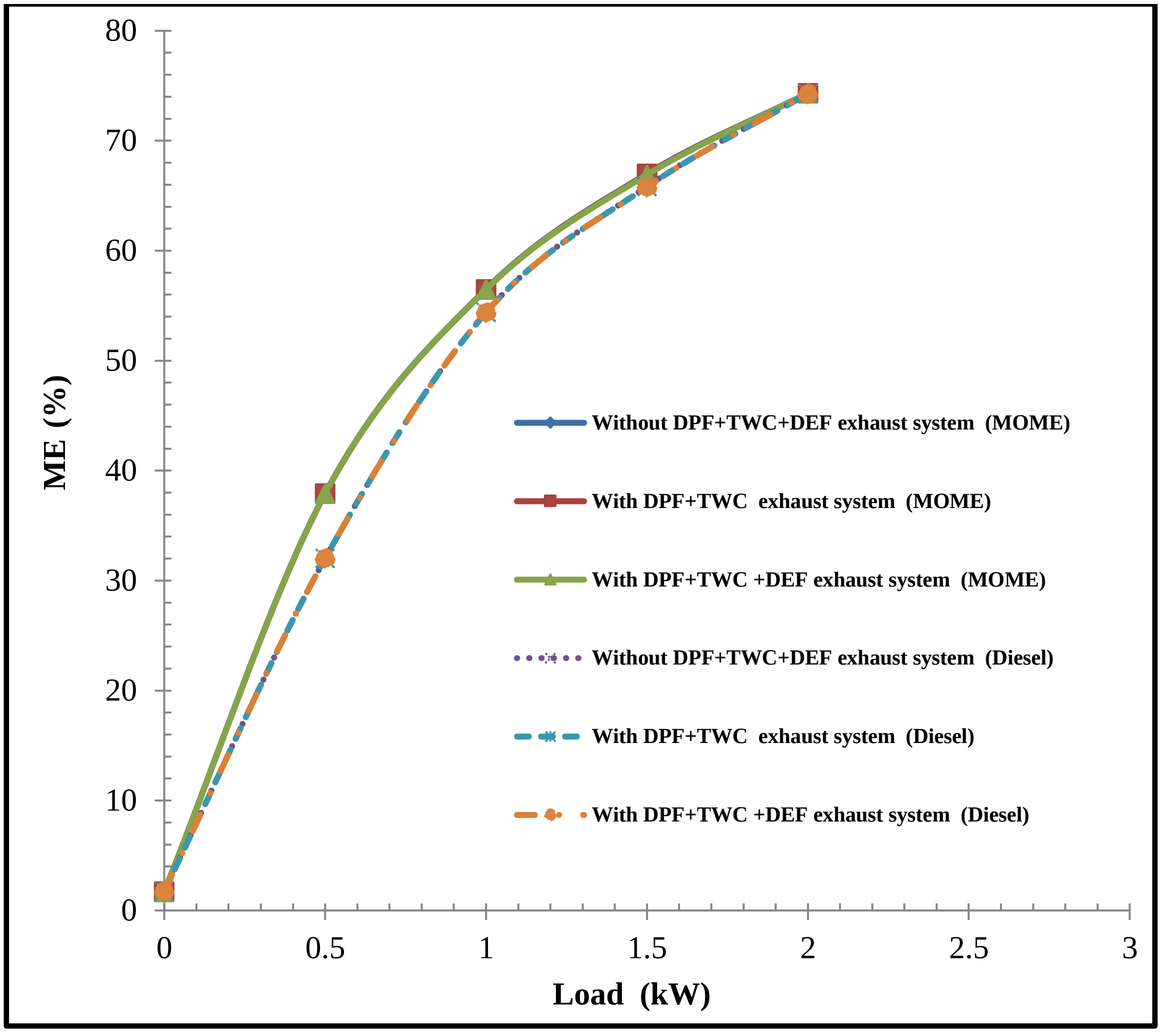


Fig. 4.3 Load vs ME

Figure 4.3 depicts the deviation of ME with respect to load with 3 different arrangements. As anticipated, resembling earlier parameters linking of converter system in the exhaust conduit does not change ME in any means due to back-pressure. As per observation there is considerable increase in the ME of MOME compared to Diesel at intermediate loads. It is owing to fact that MOME has favorable properties (refer table.1).

4.1.4 Volumetric Efficiency (VE)

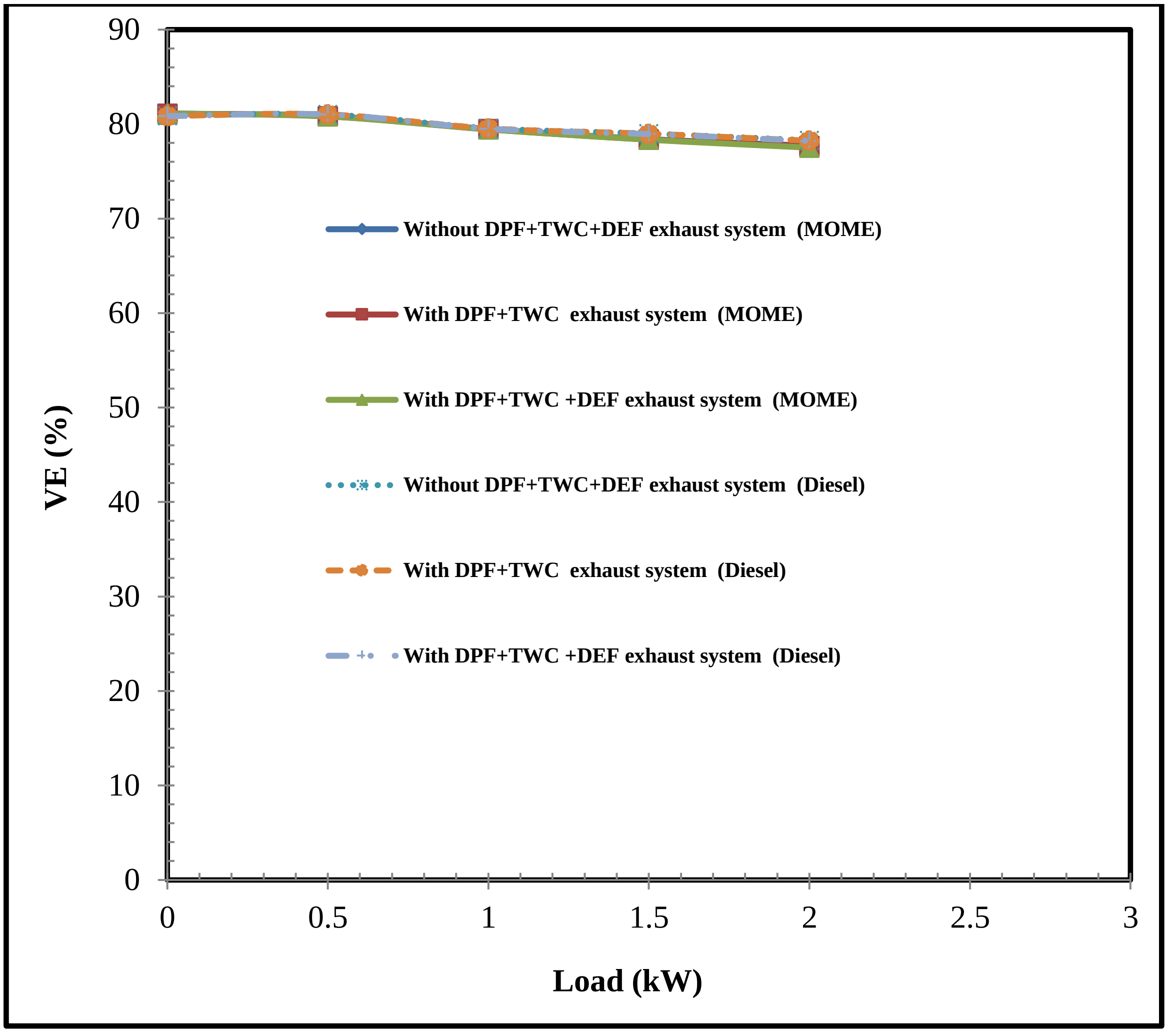


Fig. 4.4 Load vs ME

Figure 4.4 describes change of load versus VE for MOME and Diesel separately with three different arrangements. As could be seen there is a same trend in the volumetric efficiency for both MOME and Diesel separately with three different arrangements with negligible decrease. At the same time, almost under all loads it can be observed that link of DPF+TWC +DEF setup in the outlet channel does not vary the VE in any mean because of back-pressure.

4.2 Emission Parameters:

Trails conducted during CIE topped with MOME and neat-Diesel fuel independently. The test encloses a range of loads from 0kW-2kW. Toxin behaviors of CIE are observed by total of CO, HC, NOx, and CO_2. Outcomes obtain for DPF+TWC+DEF set linked to end conduit of exhaust are judged by DPF+TWC set & with no linking catalytic sets.

4.2.1 Carbon Monoxide (CO)

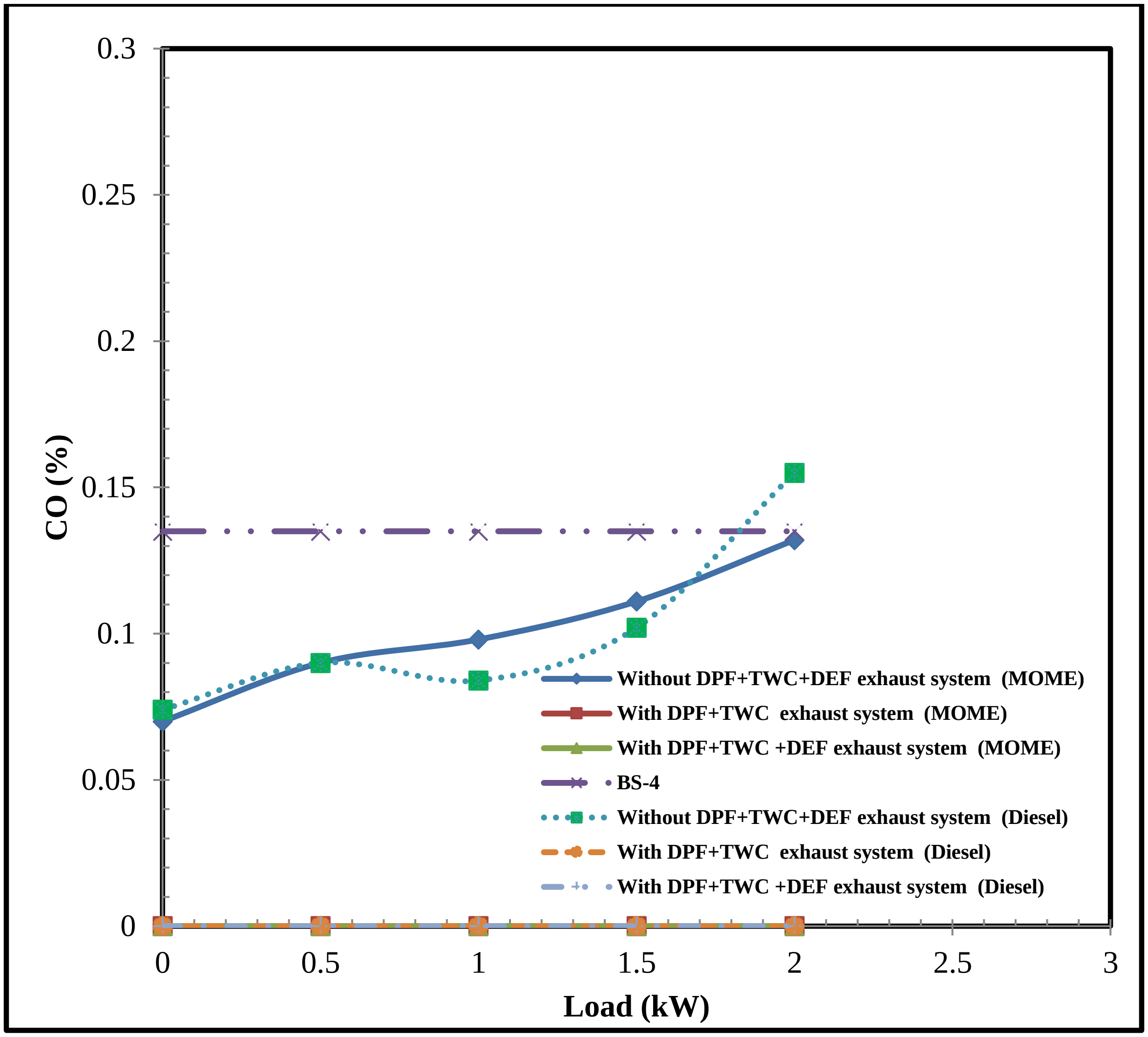


Fig. 4.5 Variations in the Carbon monoxide (CO)

Figure 4.5 clearly shows changes in CO for every 3-modes of working, powered via MOME and Diesel oil independently. CO is low while distinguished with BSIV for selected engine by varying masses for 3-arrays. CO go-up relatively by raising load up to 2kW without attaching any catalytic-array. Past linking DPF+TWC & DPF+TWC+DEF arrays, CO stays stable as 0.000%. Very little CO emitted due to MOME distinguished with dieseloil is probably owing to O_2 contented naturally there in MOME this assists in extra whole oxidation of oil. Additionally quantity of CO firstly goes-down however go-up at 100%load representing superior flaming states.

CO amounts ‘0’ during DPF+TWC and DPF+TWC+DEF sets are fixed, while judged with no connection of arrays to outlet conduit for both Dieseloil and MOME. This is owing to oxidation of CO in TWC arrangement. CO is slighter while distinct to BSIV preferred testing-set for all loads via array fixed.

4.2.2 Hydrocarbons (HC)

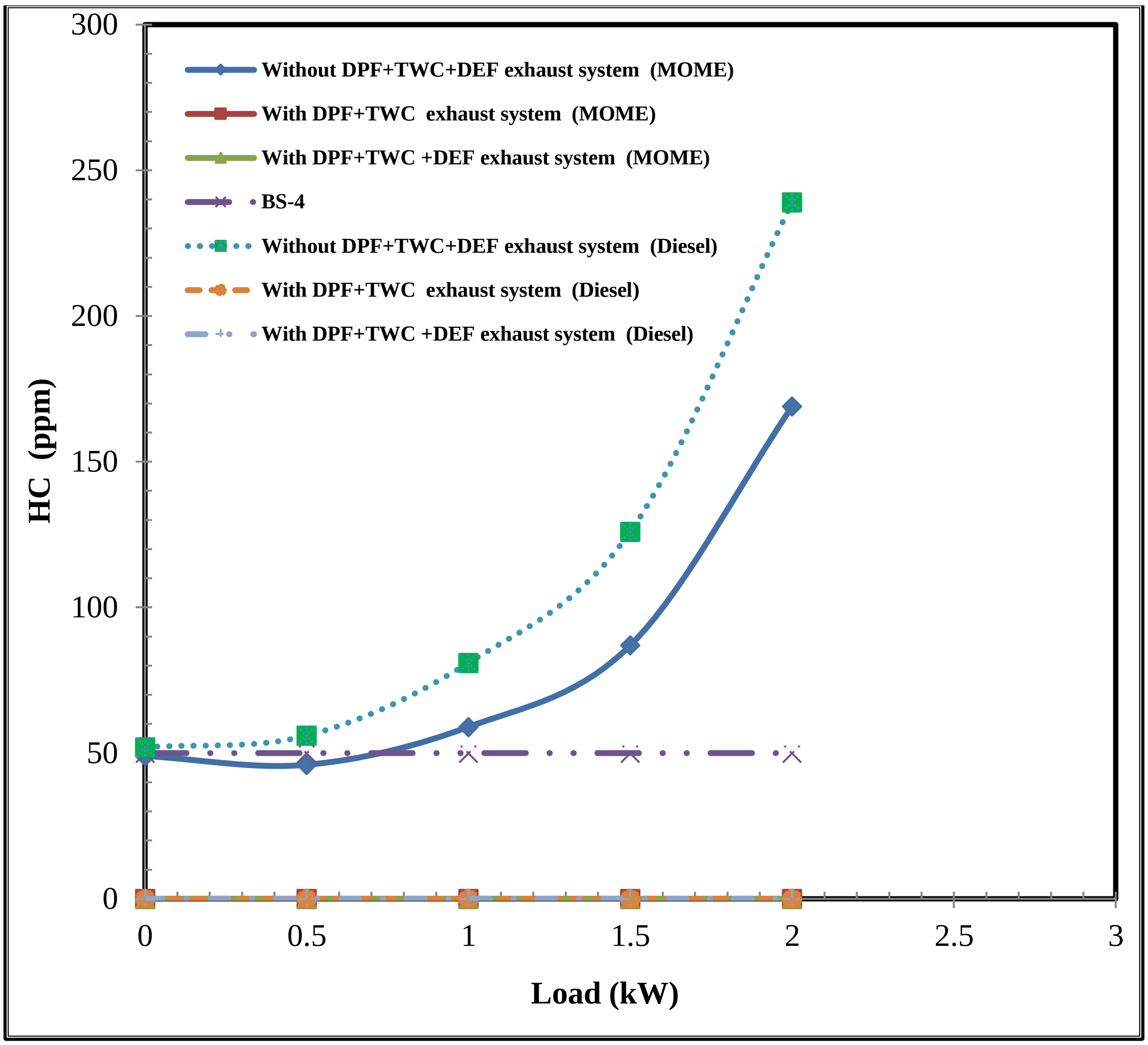


Fig. 4.6 Variations in HC

Figure 4.6 provides output for HC changes for three separate working modes using MOME and Dieseloil.

HC is higher as distinguished to BSIV for preferred CIE by elevated loads with no link of any catalytic-set. After linking DPF+TWC & DPF+TWC +DEF arrays HC change is invariable through 0.000ppm for both MOME and Dieseloil. Because of the higher gas temperature and greater cetane number of MOME, the HC for MOME exhaust is less than that of dieseloil. The higher burnt gas temperature in MOME helps to prevent the condensation of further HC, which would otherwise drop unburned HC. Due to a shorter ignition delay, higher cetane-number MOME results degrade in HC.

Quantity of HC is '0' with DPF + TWC & DPF + TWC + DEF sets, whereas Dieseloil and MOME are distinguishable without joining sets at end tube. This is due to the TWC arrangement's oxidation of the HC. When compared to the BSIV for selected testing-setup for all functional loads with retrofit approval, HC is slightly less severe.

4.2.3Nitrogen Oxides (NOx)

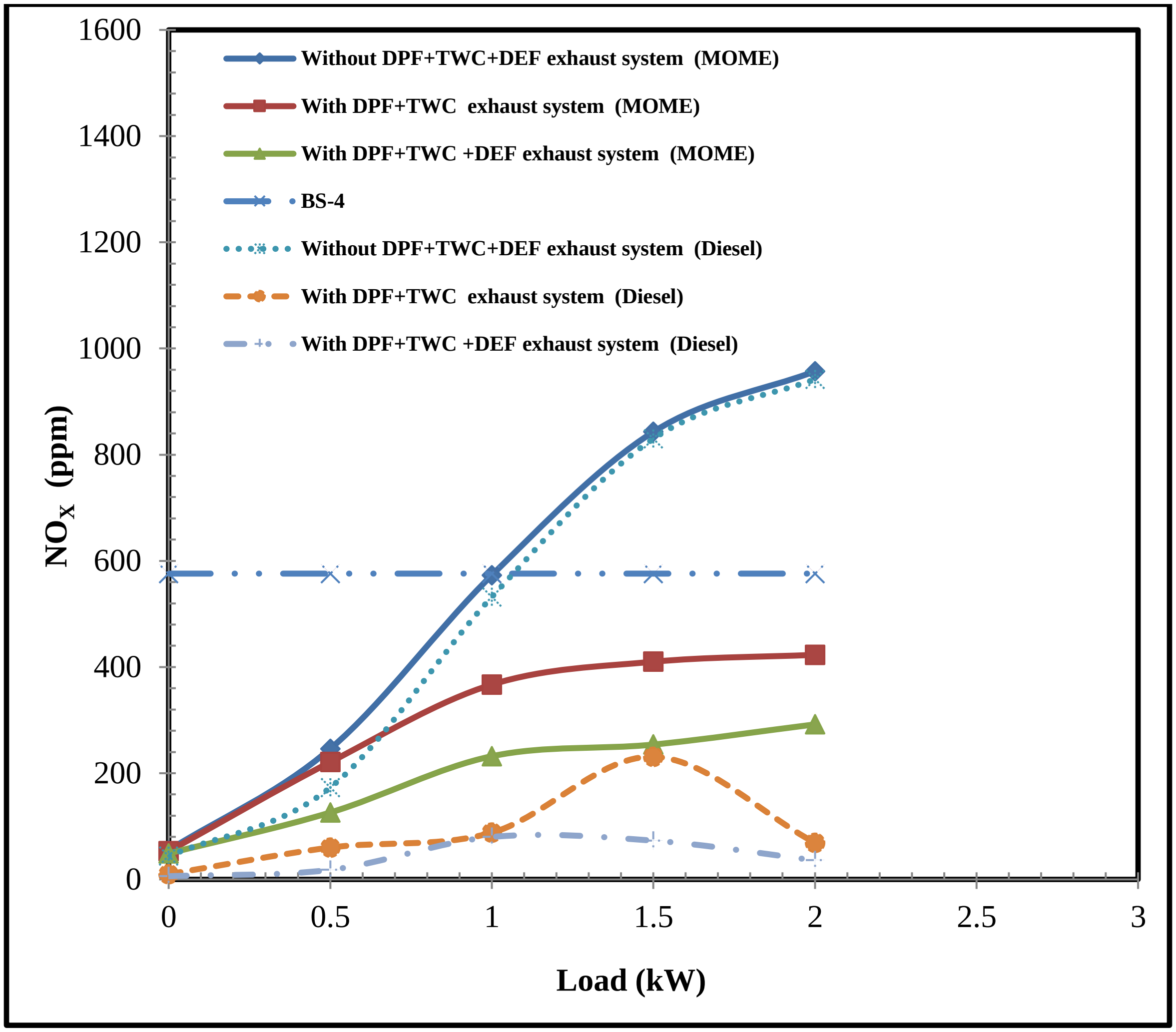


Fig. 4.7 Variations in the nitrogen oxides (NOx)

The NOx is calculated as a function of weight for different modes of diesel oil and MOME in exhaust. Figure 4.7 shows that for three modes of operation, fueling MOME produces significantly less NOx than diesel. These could be attributed to the fact that

- Biodiesel contains some O_2 which facilitates NOx generation and that the temperature of exhaust gases increases due to slight heat transfer.

- More MOME reduced cetane numbers delay ignition, advance burning, and promote NOx generation.

When no arrays are fixed, nitrogen oxides and dioxides (NOx) emissions are minimal for both DPF+TWC+DEF and DPF+TWC sets. This is resulted since of converting NOx into N_2, H_2O and CO_2. The NOx existence is small while distinguished to BSIV for preferred testing-setup for all weights by entire collection.

4.2.4 Carbon Dioxide (CO_2):

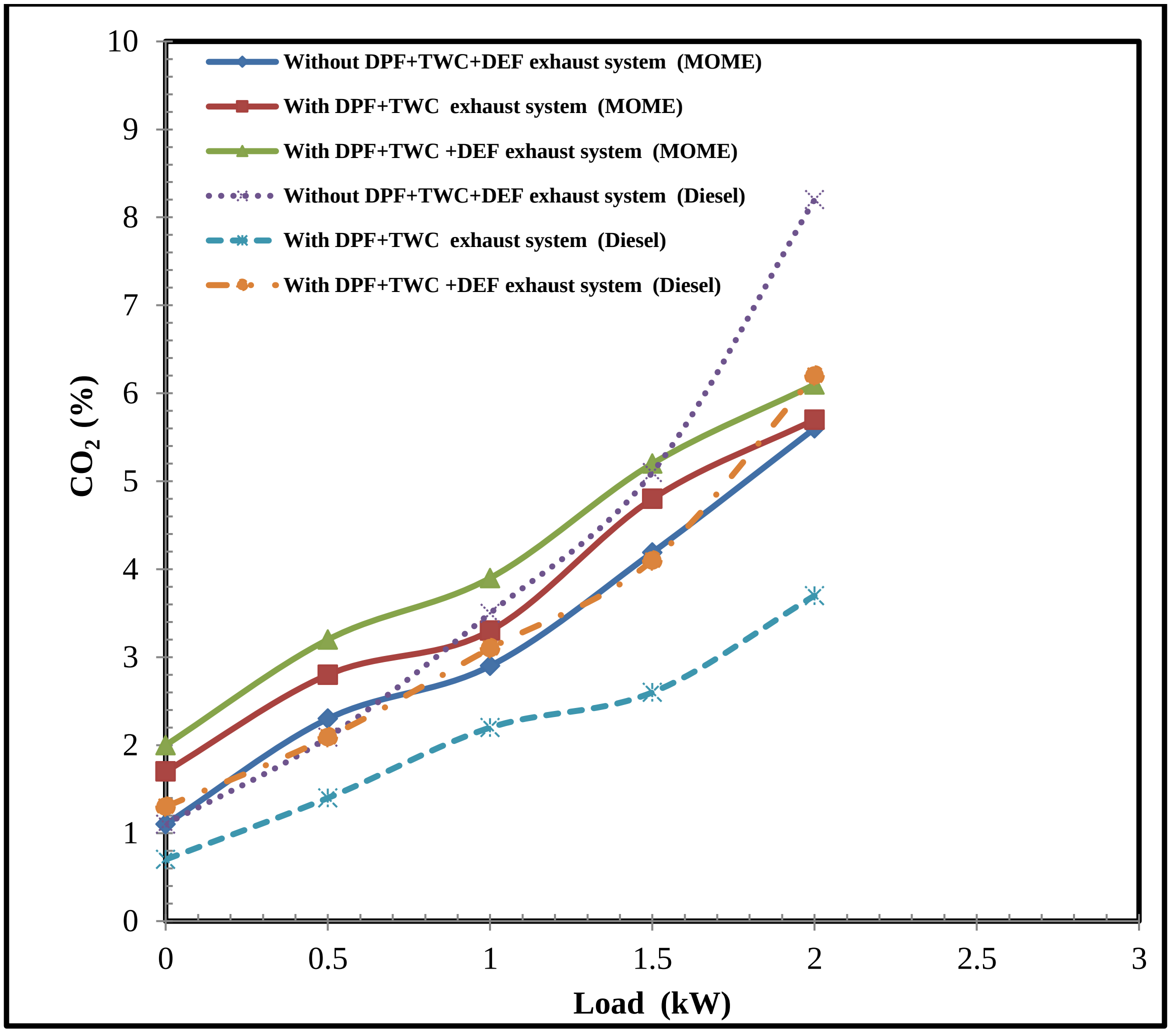


Fig. 4.8 Variations in the carbon dioxide (CO_2)

Figure 4.8 depicts the effect of the CO_2 variations for the Diesel and MOME 3-modes of operation. Based on weight, the CO_2 increases proportionally up to 2kW. This indicates that there is a minimum CO_2 value at 0 kW for both fuels for 3-arrays. From Figure 4.8 it is clearly practical that CO_2 is peak for MOME compared to Diesel oil for 3-arrangements. These outcomes leads elevated exhaust gas temperature in turn guides absolute flaming of oil by raise in the weight.

While utilizing MOME which is with lesser compressibility distinguished to diesel oil hence poorer compressibility & higher speed of sound in MOME cut ignition lag, permit combustion situations helpful for absolute combustion of oil.

5. Terminations

Based on the numerics obtained from assessments done, successive findings recapitulated as follows:

- The experiment clearly shown that employing a DPF+TWC+DEF array with MOME fuel is a practical choice without modifying the engine or compromising engine performance.
- MOME may be straightly used in CIE exclusive of several alterations with new sets.
- Distinguished with usual dieseloil, exhaust fluids CO and HC go-down, whereas NOx go-up through MOME for 3-units.
- The accessibility of rich sources and ecological responsive releases are accepted as potency of MOME important it to possible nominee as substitute energy for prospect CIE.
- From the research completed it is evidently instituted that DPF+TWC+DEF array as unsurpassed-suitable exchange for CIE exhaust-aftertreatment setup as this array produces less-significant/no-discharges than conventional setup for all load circumstances.

Symbols/notations

BSFC	Brake specific fuel consumption
BTE	Brake thermal efficiency
CI	Compression ignition
CIE	Compression ignition engine
CO	Carbon monoxide
CO_2	Carbon dioxide
DI	Direct injection
DOC	Diesel oxidation catalyst
DEF	Diesel exhaust fluid
DPF	Diesel particulate filter
EGR	Exhaust gas recirculation
HC	Hydro carbons

H_2O	Water
ITR	Injection timing retardation
kW	kilo Watt
LTC	Low temperature combustion
MOME	Mahua Oil Methyl Ester
N_2	Nitrogen
NH_3	Ammonia
NOx	Nitrogen oxides
O_2	Oxygen
OEM	Original equipment manufacturer
PM	Particulate matter
RME	Rapeseed methyl ester
SCR	Selective catalytic reduction
TWC	Three way catalyst
VOCs	Volatile organic compounds
WI	Water injection
%	Percentage

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