NVEO
Natural Volatiles & Essential Oils

Trial Test On CI Engine With New After-Treatment Setup For Emissions Using Mahua Oil

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Abstract

A novel type of emission after treatment arrangement consisting DPF, TWC converter by fresh variety of Ad-blue feeding unit with human regulation, distribution part and distribution row approach to decide extent of improving the competence of existing Urea and SCR arrangement with neat mahua oil (M100) as fuel. Result indicates ~100% decrease in both CO and HC emissions through retrofit. Simultaneously observed fall in the NOx, when compared to traditional arrangement.

Keywords: CIE, urea-SCR, DPF, Ad-blue, Mahua oil, emissions, TWC.

1. Introduction

The usage of emission after treatment arrangement for CIE is a gauge to execute the regulation necessities. SCR combined by means of $(NH_2)_2CO$ liquids contemplated as hopeful for this enhanced presentation. Especially $(NH_2)_2CO$ filtration through no-fuel fine plus more robustness toward sulfur containing oils. Europe on-road demos of the $(NH_2)_2CO$-SCR arrangements be performed moreover realistic implementation of the $(NH_2)_2CO$-SCR units worked jointly by transportations used for feeding $(NH_2)_2CO$ liquids. However, there are troubles to be resolved in favor of realistic application of $(NH_2)_2CO$-SCR units. 1st is the little commencement on behalf of NOx decrease and NH_3 slip under less emission temperatures and momentary circumstances faced in actual working environs.

The SCR procedure is a fixed model, but still industrially not attested equipment for NOx emission regulation for vehicles. Especially, NH_3-SCR attributed by a reductant [NH_3] mixed with emission stream is renowned as a moldable solution for movable CIE NOx emissions. Most important dispute in vehicle implementation of NH_3-SCR procedure is performance improvement of de-NOx at less emission temperature (i.e. less than 300ºC) as well as aboard storeroom of $(NH_2)_2CO$. Best possible technique available to encourage de-NOx action at less temperature is to guide the reaction to go-through quick SCR pathway.

Most significant point to be contemplated is vaporization of NH_3-liquid i.e. Ad-blue solution with emission. For enhancement of surface - chemical reaction and gas – phase - chemical reaction, in the present work it is trialed with evaporation by novel type DEF (or)Adblue -Dosing unit by human regulation, Supply-unit & Supply-Line (copper-tube) wrapped roughly surrounding the exhaust tube to lift the DEF temperature slightly.

The planet is presently taking ecological decay and nonrenewable-fuel exhaustion problems. Numerous evaluations have tried to find out the replacement for nonrenewable-fuel. Burning of bio-diesel in the CIE decreases the different pollutants. Therefore, by utilizing bio-diesel in the present original CI engines will improve the ecological importance by dropping the amount of green-house gasses.

1.1. Test fuel plus properties

Madhuca long ifolia is associated to genus of sapotaceae. It is an indian humid tree available around the northern piece. It raises 20m in height and cultivates at fast rate. Thus, there is excess accessibility of Madhuca-fuel that can be contemplated as possible contender for substitute oil. Furthermore, by industrializing the use of Madhuca-fuel as replacement oil, the household and country farming financial system will be reinforced. Properties of test fuel are demonstrated in Table 1.

Table 1 Properties of test fuel

PROPERTIES	NEAT MAHUA OIL (M100)
Chemical formula	$C_{15}H_{31}CO_2CH_3$
Density @ 18 C (gm/cc)	0.882
Kinematic Viscosity @35 C (mm2/s)	4.2
Calorific Value (kJ/kg)	38108
Latent heat of vaporization (kJ/kg)	685.1
Cetane Index (CI)	52
Flash point in C	140

1.2.

1.3. DPF

The channel encloses usually Al_2O_3 wash cover carried on honey-comb profile earthenware block as revealed in Fig.1.

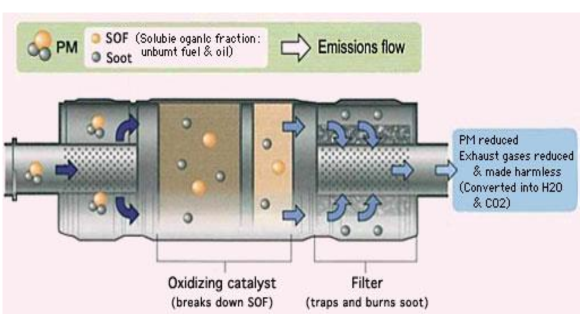

Fig.1DPF

1.4. TWC

This channel gets its title since regulating 3 chief pollutants in an exhaust viz., NOx, VOC's plus CO. The channel normally holds Al_2O_3 wash cover carried on honey-comb profile earthenware block as depicted in Fig.2. Expensive materials were layered over alumina. Dynamic portion of medium is additionally separated as oxidation & reduction spots. Combinations of platinum-rhodium elements perform as dynamic places toward succeed reduction responses, whereas platinum-palladium performs as dynamic elements for oxidation responses.

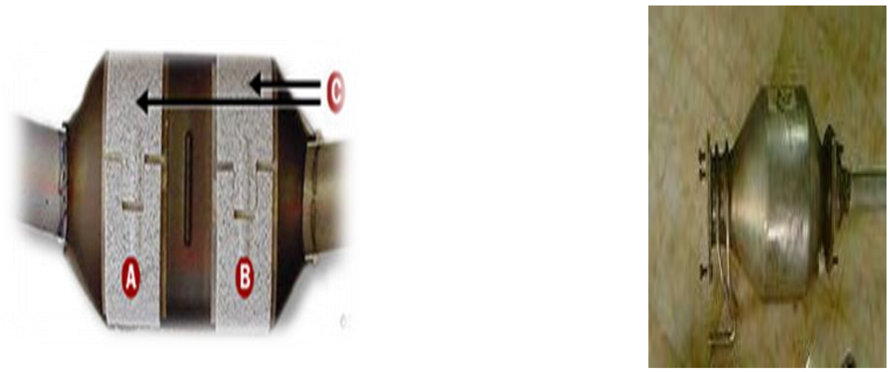

Fig. 2TWC Converter

A: Reduction Catalyst

B: Oxidation Catalyst

C: Honeycomb Ceramic Structure

Reduction of nitrogen oxides to nitrogen and oxygen:

$$2NO_x \rightarrow xO_2 + N_2$$

Oxidation of carbon monoxide to carbon dioxide:

$$2CO + O_2 \rightarrow 2CO_2$$

Oxidation of unburnt hydrocarbons (HC) to carbon dioxide and water:

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

1.5. Adblue / DEF

DEF is a chemical mixture prepared by 67.5% pure-H_2O & 32.5% granular-$(NH_2)_2CO$. DEF acts as transportation means for NH_3 required for reducing NOx from vehicle-engine to N_2, H_2O & CO_2.

Urea Decomposition Reaction (when DEF is introduced into the hot stream of exhaust gas water evaporates and urea thermally decomposes to form NH_3 and CO_2)

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

Overall reaction for Urea Decomposition

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

Ammonia Reaction (in the presence of oxygen and a catalyst)

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

2. Literature Review

Resitoglu [1] found that the major considerable contaminants formed in biodiesel-fuelled CIE are PM, NOx, HC, and CO, among this NOx constitutes higher than 50%, chased by PM. Hoekman et al. [1-2] worked on bio-diesel and bio-diesel mixtures are used in CIE, number of examiners confirmed that pollutants CO, HC and PM have been significantly decreased whereas the NOx observed to be raised. Sindhu [3] researched with split inoculation; a little quantity of oil is grabbed in the initial pulsation is to warningly decrease NOx suitable to the pre-mixed burning. Split inoculations were found to be efficient in NOx decrease. In current years, selective catalytic reduction, an exhaust aftertreatment method observed to be successful in NOx decrease, even though its passing in present generator necessitates exhaust alterations which is not economical. LTC methodologies are implemented in contemporary CIE to decrease NOx and PM by Praveena [4]. Yuvarajan et al. [5-7] experimented on bio-diesel and its diverse mixtures utilized in CIE guide to rise in NOx and BSFC than unadulterated diesel unsettled to enhanced O_2 percentage in mixtures.

Relatively, bio-diesel oils present a decrease of dangerous pollutants such as PM, CO, & HC; conversely, it creates higher NOx was proved by Janaun et al. [8-9] The major dangerous NOx influences the surroundings via acid-rainfall, individual illness, etc. Further, Latha et al. [10-11] investigated on CO and NOx are chief pollutants in the development of troposphere-O_3. Bio-diesel with 60 to 65% of H_2O mixed with oil can decrease upto 50percent NOx, more WI (H_2O-injection) percentage be capable of decrease more NOx under different load circumstances identified by Tauzia [12]. Hountalas [13] deliberated two techniques of NOx decrease methods that are H2O-injection & H2O-suspension in DI-CIE. Results revealed that, H_2O-insertion is improved compared to H_2O-blend; conversely, above two procedures were competent as contrasted to ordinary CIE function.

Further, Sahin [14] discovered emulsification procedure leads to rise in the HC & CO due to the decrease in burning cavity hotness, which can afterward influence the burning competence. Basha [15] examined the task of nano-additive utilized in emulsified bio-diesel in CIE. They explored on emulsified bio-diesel of 83% Jatropha bio-diesel +15% H_2O + 2% surfactant. Depending on testing in a 1-cylinder engine, it is found that the NOx decreases by 21%, the PM decreases by 15% though the HC rises by 46%, BTE improved by 2.5%, while BSFC decreased by 2.6%.

Few of the investigators Swaminathan et al. [16-17] implemented concurrent methodologies to get improved solutions such as fuel-additive with EGR and ITR with EGR. Related to the above situation, Saravanan [18] researched the joint influence of EGR, ITR and injection-pressure on RME bio-diesel fuelled 1-cylinder CIE. They observed that, the minimal grouping of engine factors by utilzing Taguchi- technique decreases the Fig. of investigational effort and found that NOx decreases with slight reimbursement on the effectiveness and other contaminations. Manuscript Assessed on NOx decreasing practices such as WI, H_2O-emulsification, injection-timing retardation and concurrent tools and its influence on different working factors conceded-out in bio-diesel fuelled CIE by Prabhu Appavu [19].

The conceptual model of Urea Dosing System Denoxtronic 3.1 developed by Bosch [20] has been in succession production at numerous OEMs since mid 2008. Implementation of the Denoxtronic 3.1 previously facilitates fulfillment with Euro 6 and Tier2 Bin5 restrictions & is the base for most of the recent work in the area. Likely applications: The Denoxtronic 3.1 is principally designed for utilize in passenger cars and in the light-duty sector.

Furthermore possible implementations present in the off-highway section for engines in the range 56…100 kW. {SCR Technology for NOx Reduction: Series knowledge and State of Development Manuel Hesser, Hartmut Lüders, Ruben-Sebastian Henning Robert Bosch Corporation / Robert Bosch GmbH} From above survey, different practices implemented in CIE such as WI, H_2O-emulsification, engine alteration and concurrent methodology to decrease NOx were vitally evaluated. Also discussed the consequences of emissions, performance and burning features by different NOx decreasing methodologies in bio-diesel & fuel-additive mixtures powered CIE. Mahalingam [21] studied about pure madhuca oil bio-diesel is mixed with dissimilar quantity of octanol in motionless CIE to monitor its emission characteristics. It is resulted in noteworthy decrease in all the emissions related with madhuca oil bio-diesel by adding octanol at unusual magnitudes. Alghafis et al. [22-23] investigate experimentally the engine performance and combustion parameters were augmented, at 28 degree IT, with a bio-fuel of B20+10lpm of hydrogen when compared with all other combinations considered in the experimentation. Concurrently found that vibrations and emissions were dropped for B20+10lpm of hydrogen flow at 28 degree IT. Additionally, the effects on the emissions and performance parameters in a single cylinder diesel engine fueled with diesel and waste cooking oil blends were studied and the optimized condition for the performance and emissions characteristics was found to be at 225 bar injection operating pressure. The emissions decreased with increase in WCO blend percentage however; there was a marginal drop in the performance of the engine.

From the above literature following observations can be drafted:

i. NOx can be reduced up to 37 to 50% by WI practice in bio-diesel engines and also CIE with a little rise in BSFC & CO.
ii. It's clear that H_2O-biodiesel-suspension decreases NOx around 10 to 60% contrast to traditional oil. Conversely, numerous examiners determined emulsification raises CO and HC by 16 to 94% and 45 to 55% respectively.
iii. Injection time retardation decreases NOx up to 8 to 40.5% than ordinary injection timing however raises other pollutants. Although, it also simultaneously decreases BTE & raises BSFC.
iv. Parallel tools have many benefits compared to individual due to numerous methodologies similar to additive-EGR, ITR-EGR, etc. It is determined that NOx reduced up to 95%; conversely, it raises PM, HC, and CO considerably.

In-order to overcome above all issues related to emissions without affecting performance and combustion characteristics the following experimentation was carried out.

3. Details of Experimentation

3.1. Test rig arrangements

The test-rig comprise of 1-cylinder 4-stroke DI-CIE with 80mm bore, 110mm stroke length, rated speed of 1500rpm, 5BHP/3.7KW rated power and water cooled engine.

Fig. 3 Experimental Setup

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

1. kirloskar-CIE
2. Diesel tank
3. Control panel
4. DPF
5. DEF tank with supply module & battery
6. TWC
7. Multi-gas analyzer

3.3. Engine Specifications

- 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

3.4. Novel DEF arrangement:

Feeding amount	162g/h @ 1.5bar
Nozzle Type, Material & diameter	1- Hole, Brass & 400 µm (Sauter Mean Diameter)
Environmental operation settings Distribution unit : Dosing Module :	 -30…..70^{0}C -30…..140^{0}C
Operating Voltage	12 V
Distribution line length between Distribution unit & Feeding unit	3805 mm
Distribution Line Material, Cross-section	Cu, Circular tube
Adblue-Tank Material	Plastic

4. Outcomes and Deliberation

Tests are performed while CIE powered by neat mahua oil. The trial enclosed a variety of loadings from zero to 2kW. The pollutant qualities of CIE were experiential in amount of HC, CO, O_2, NOx, and CO_2. The consequences got for DPF+TWC converter +DEF unit coupled at tail pipe of drain were contrasted with DPF+TWC converter unit and without connecting any of the above-mentioned units.

4.1. Carbon Monoxide (CO)

The result for the variations in the carbon monoxide (CO) is presented in the Fig. 4.1, for all the three modes of operation. The CO is lesser when contrasted to the BS-IV & Euro VI standards for chosen engine at different loads. The CO rises proportionally with increasing load up to 2kW without linking any unit. This designates the presence of minimal value of CO at 0kW. From Fig. 4.1 it can be evidently observed that CO is 0.132% high for 2kW without linking any unit. After connecting DPF+TWC and with DPF+TWC+DEF units the CO variation is constant with 0.000% values.

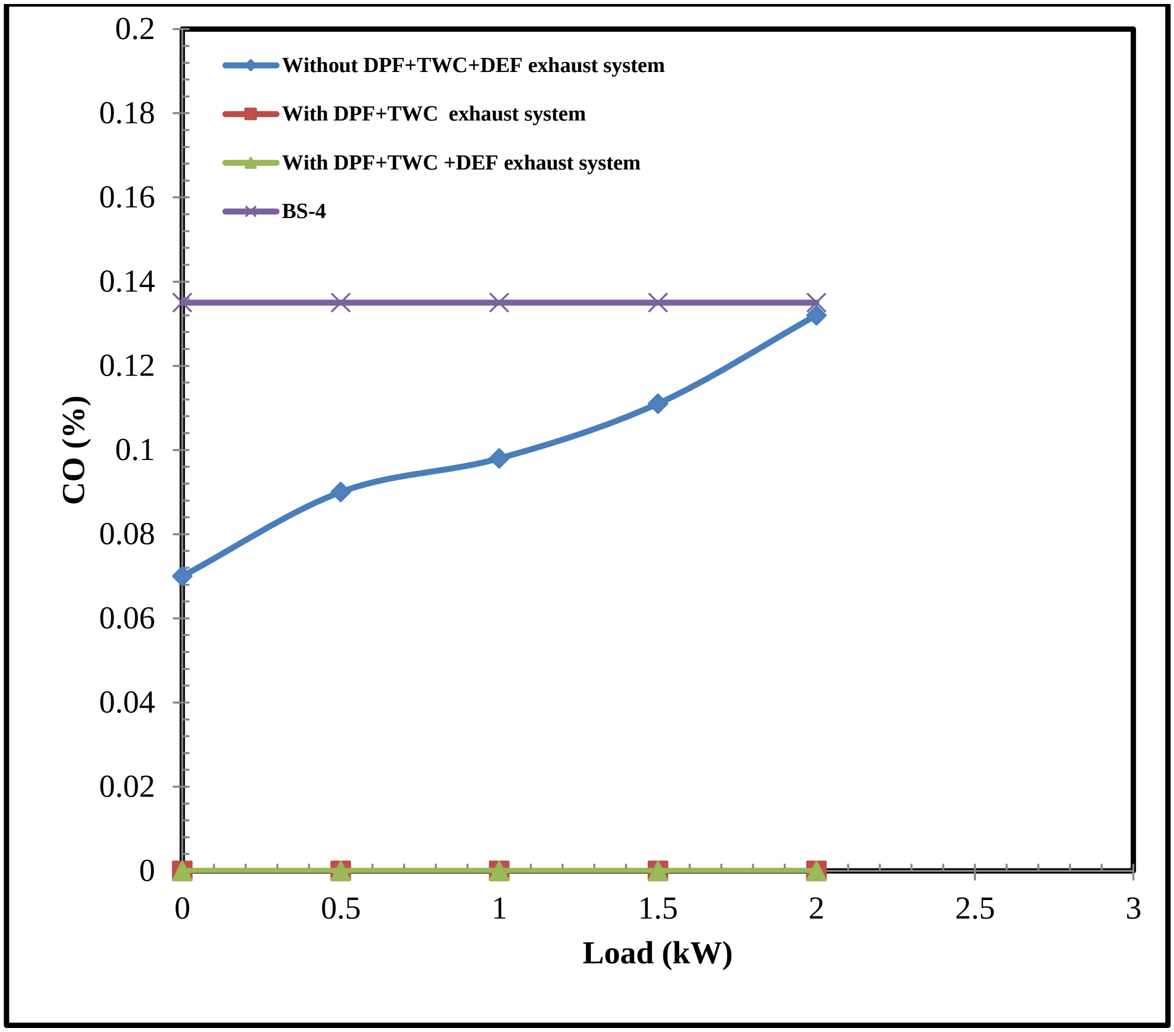

Fig. 4.1Variations in the carbon monoxide (CO)

4.2. Hydrocarbons (HC)

The result for the variations in the unburnt hydrocarbon (HC) is presented in the Fig. 4.2, for all the three modes of operation. HC is lesser while contrasted to BS-IV standards for chosen CIE at different loadings. The HC increases with respect to load up to 2kW without linking any unit. After connecting DPF+TWC and DPF+TWC +DEF units the HC variation is constant with 0.000ppm values. This shows the presence of minimal value of HC at 0kW. From Fig. 4.2 it is noticeably observed that HC is 169ppm high for 2kW without linking any unit.

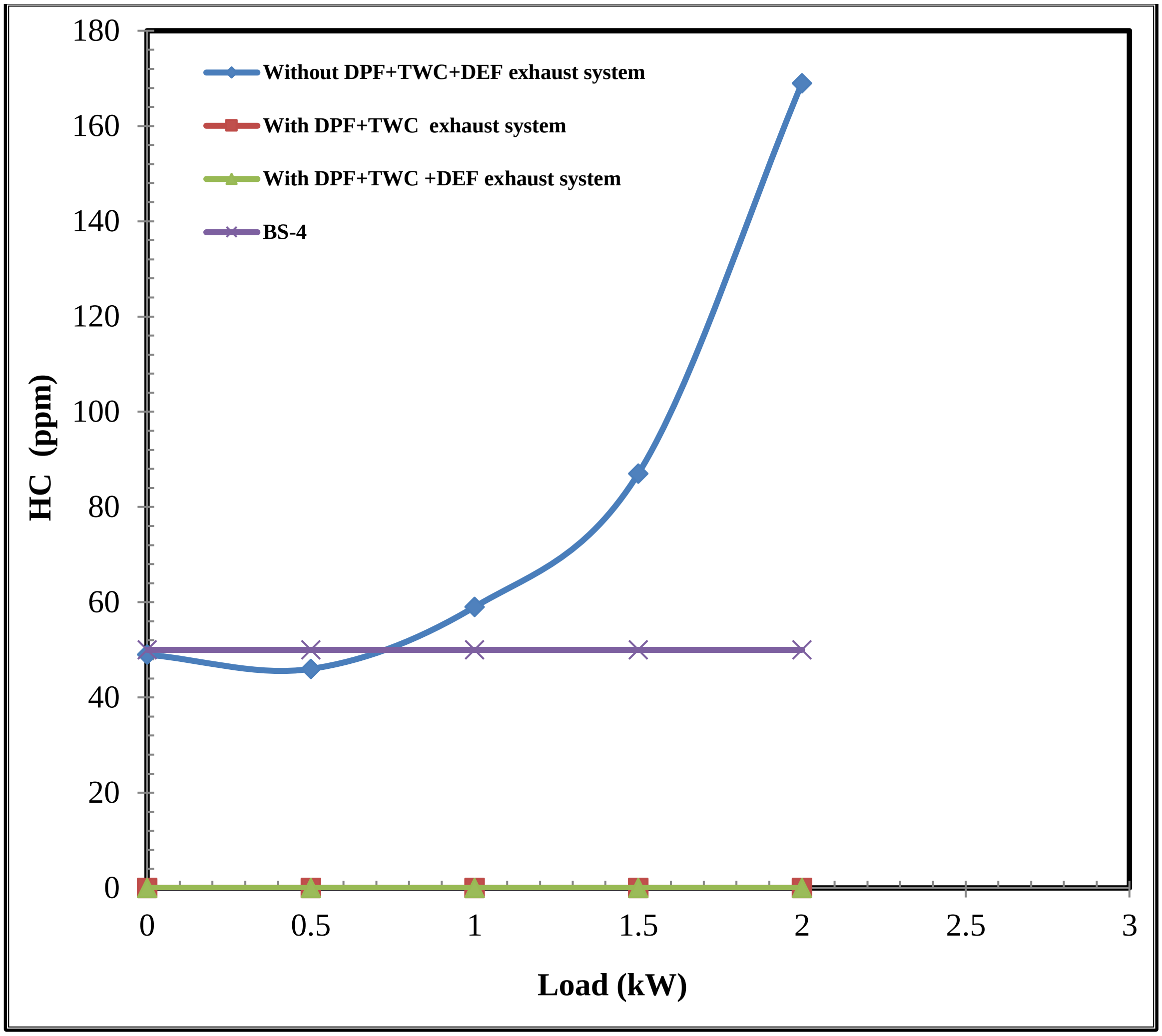

Fig. 4.2 Variations in the unburnt hydrocarbon (HC)

4.3. Nitrogen Oxides (NOx)

Variation in the nitrogen oxides (NOx) is presented in the Fig. 4.3 for all the three modes of operation. The NOx increase proportionally with respect to load up to 2kW.This results the presence of minimal value 49ppm of NOx at 0kW with linking entire unit. From Fig.4.3 it is evidently found that NOx is 957ppm high at 2kW without linking any unit. After connecting DPF+TWC unit, the NOx increase proportionally with respect to load up to 2kW. But the values of NOx were less when compared to above mode of operation. When DPF+TWC+DEF unit is connected, the NOx increase proportionally with respect to load up to 2kW and the values were less compared to second mode of operation.

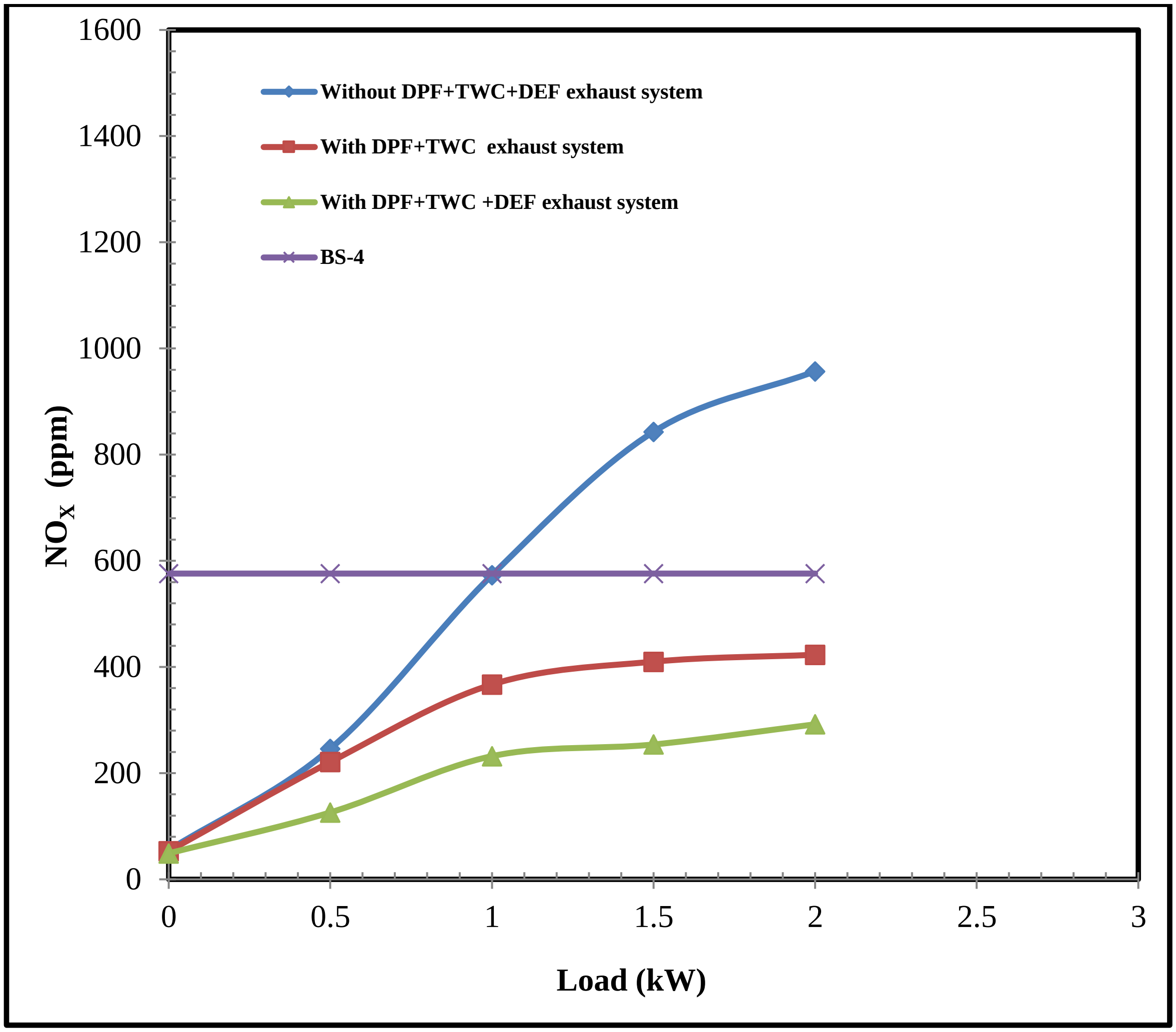

Fig. 4.3 Variations in the nitrogen oxides (NOx)

4.4. Carbon Dioxide (CO_2):

The result for the variations in the carbon dioxide (CO_2) is presented in the Fig. 4.4, for all the three modes of operation. The CO_2 increase proportionally with respect to load up to 2kW.This shows the presence of minimal value 1.1% of CO_2 at 0kW without linking any unit. From Fig. 4.4 it is obviously observed that CO_2 is highest for 2kW with linking entire unit. After connecting DPF+TWC, the CO_2 increase proportionally with respect to load up to 2kW. But the values of CO_2 were more when compared to above mode of operation. When DPF+TWC +DEF unit is connected, the CO_2 increase proportionally with respect to load up to 2kW but the values are more compared to second mode of operation. As a universal law, more the CO_2 amount, higher capable the engine is working.

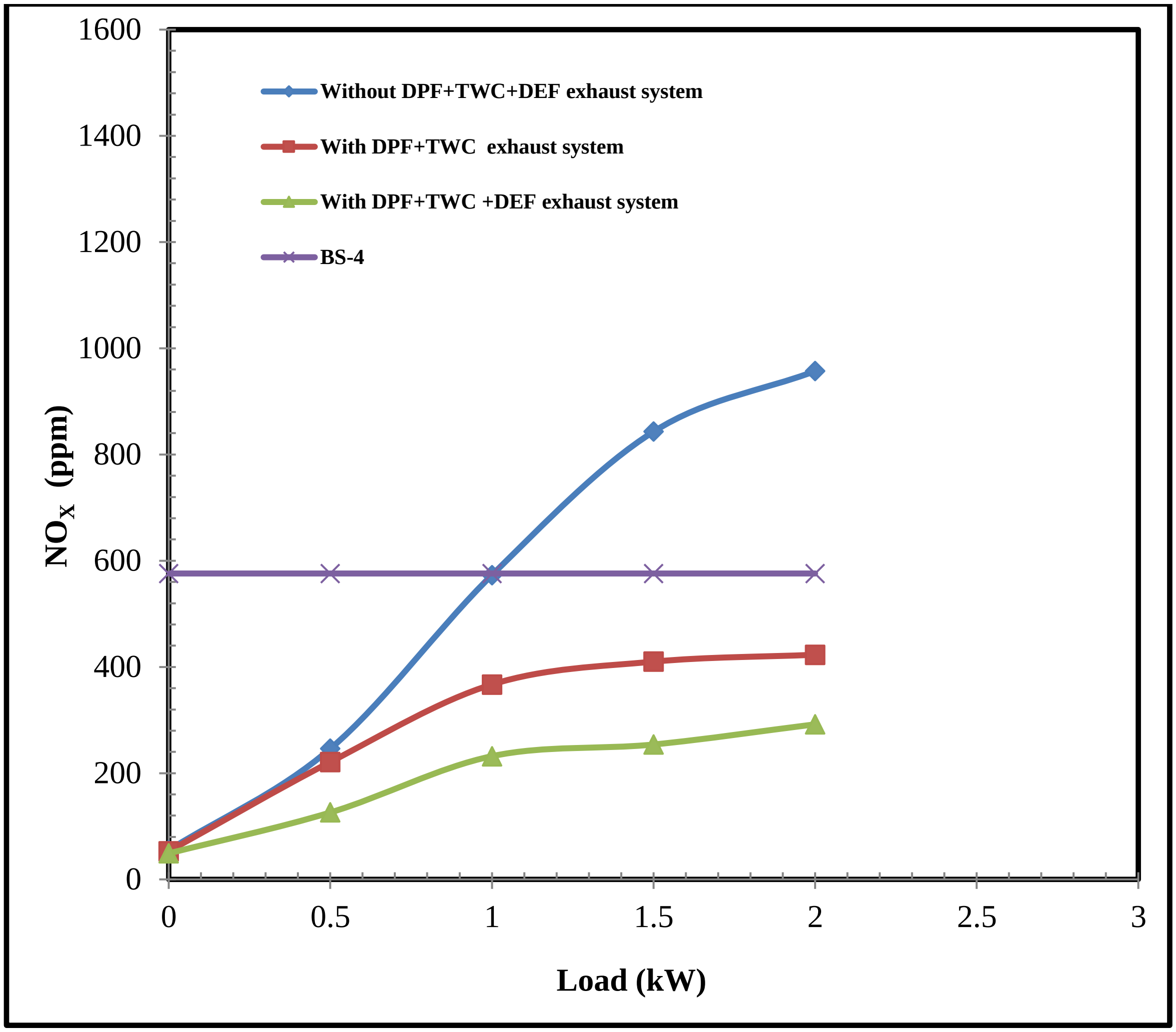

Fig. 4.4 Variations in the carbon dioxide (CO_2)

5. Conclusions

Depending on the values got from the trials conducted, subsequent judgments are drafted.

* CO amount is zero for DPF+TWC and DPF+TWC+DEF unit linked, when contrasted without connecting any unit to exhaust pipe. This is due to oxidation of CO in TWC system. The CO is lesser when contrasted to BS-IV standards for chosen test-rig under every working load by arrangement fitted.

* Amount of HC is '0' for DPF + TWC and DPF+TWC+DEF unit linked, when contrasted without connecting any unit at the tail pipe. This is because of oxidation of HC with TWC system. The HC is lesser when contrasted to the BS-IV standards for chosen test-rig under every working load with retrofit arranged.

* CO_2 is high for DPF+TWC and DPF+TWC+DEF unit linked, when contrasted without connecting any unit at the exhaust pipe. This is due to reactions taking place inside of catalytic converter.

* Nitrogen oxides / dioxides (NOx) contamination is low for both DPF+TWC+DEF unit and DPF+TWC attached, when differentiated without any unit fitted. This results because of reduction of NOx into nitrogen, water and carbon-

dioxide. The NOx presence is minor when contrasted to the BS-IV standards for chosen test-rig under every working load with whole arrangement.

From the investigation done it is clearly found that DPF+TWC+DEF unit is best-appropriate alternate for CIE exhaust after treatment arrangement as this unit generates smaller/no emissions than traditional setup under every load situation. And neat mahua oil can be suitable future fuel for CIE.

Symbols/notations

BSFC Break specific fuel consumption

BTE Break 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

M100 Neat mahua oil

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

Conflicts of Interest

This is to assure that there is no any type of conflict of interest in publication of original research work done.

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