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Experimental Investigation on Modified Exhaust After treatment System for Diesel Engine Emissions

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***Abstract-* A new kind of exhaust after treatment system having Diesel Particulate Filter, Three Way Catalytic (TWC) converter (in substitution of SCR & Oxidation catalyst) with new kind of DEF/Adblue-Dosing Module with Manual Control, Supply module and Supply Line strategy, is prepared in order to determine the scope for enhancing the efficiency of a Urea-SCR system. The results show that there is a ~100% reduction in the CO and HC emissions after arranging the setup. It is also found that on an average there is a 93% reduction in the NO_x.**

Keyword- **Diesel Engine; TWC; Urea-SCR; DPF; DEF/ Adblue; Emissions.**

1. INTRODUCTION

The introduction of exhaust gas after treatment systems for diesel engines is a measure to fulfill the legislation requirements [1]. Selective catalytic reduction (SCR) with urea solutions are considered to be promising for this better performance [7]. Particularly the urea-purification with no fuel penalty and high durability to sulfur-contained fuels. Therefore, in Europe, on road demonstrations of the Urea-SCR systems are conducted and practical application of the Urea-SCR systems is being discussed together with the infrastructures for supplying urea solutions. However, there are problems yet to be solved for practical usage of Urea-SCR systems. The first one is the low activation for NO_x reduction and NH_3 slip under low exhaust gas temperatures and transient conditions encountered in real operating conditions [2]. The selective catalytic reduction (SCR) process is a well-established concept, but yet commercially not proved technology for nitrogen oxide [NO_x] emission control for automobiles. In particular, ammonia [NH_3] SCR featured by a reluctant [NH_3] added to the exhaust gas is recognized as a flexible remedy for mobile diesel NO_x emission. One of the major challenges in the automobile application of the NH_3 SCR process is the enhancement of the de-NO_x performance at low exhaust gas temperatures below 300ºC and on board storage of Urea [3]. One of the feasible methods to promote de-NO_x activity at low temperatures is to lead the reaction to pass through the fast SCR path. One of the important factors that is to be considered is evaporation of NH_3 liquid [4] i.e. Adblue solution with exhaust gas [6],[7]. For the betterment of surface reaction and gas phase reaction, I have tried with vaporization by new kind of DEF/ Adblue-Dosing Module with Manual Control, Supply module & Supply Line (made of copper material) wounded around the exhaust pipe in order to raise the temperature of DEF. The present investigation concern with experiment on Diesel engine test-rig in order to determine the exhaust gas emissions at the end of tail pipe at different loads by arranging the setup proposed.

A. Diesel Particulate Filter

The catalyst contains Fibrous ceramic filters are made from several different types of ceramic fibers that are mixed together to form a porous media. This media can be formed into almost any shape and can be customized to suit various applications. The porosity can be controlled in order to produce high flow, lower efficiency or high efficiency lower volume filtration. Fibrous filters have an advantage over wall flow design of producing lower back pressure. Ceramic wall-flow filters remove carbon particulates almost completely, including fine particulates less than 100 nanometers (nm) diameter with an efficiency of >95% in mass and >99% in number of particles over a wide range of engine operating conditions. Since the continuous flow of soot into the filter would eventually block it, it is necessary to 'regenerate' the filtration properties of the filter by burning-off the collected particulate on a regular basis [9]. Soot particulates burn-off forms water and CO2 in small quantity amounting to less than 0.05% of the CO2 emitted by the engine, as shown in below Fig. 1.

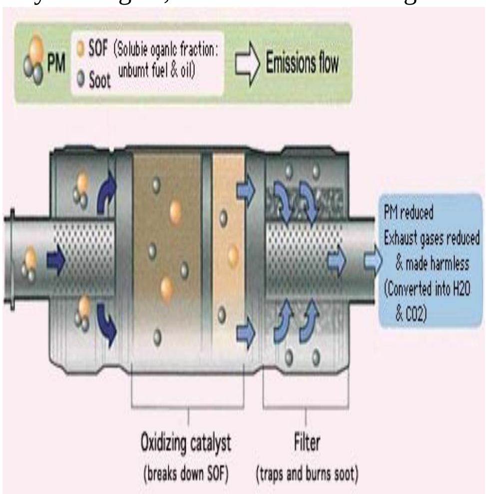

Fig. 1. DPF

B. Three Way Catalytic (TWC) Converter

This catalyst takes its name from controlling the three major emissions in an engine that are NO_X, VOCs and carbon monoxide. The catalyst commonly contains an alumina wash coat supported on a honeycomb shape ceramic brick as shown in Fig. 2. Precious metals are

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coated onto the alumina [5]. The active part of the catalyst is further divided into oxidation and the reduction catalyst sites. The platinum/rhodium components act as the active sites to carry out reduction reactions, while platinum/palladium acts as the active component for oxidation reactions [10].

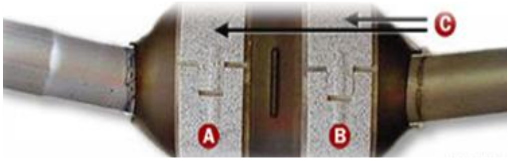

Fig. 2. Section of TWC

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

C. Adblue / DEF

Diesel Exhaust Fluid (DEF) is a solution made of purified water and 32.5% urea. This is the carrying agent for the ammonia needed to reduce nitrogen oxide (NOx) emissions from vehicles into nitrogen, water and carbon-dioxide [6], [7], [8], [10].

Urea Decomposition Reaction

$4(NH_2)\ _2CO => 2NH_3 + CO_2$

Ammonia Reaction

$4NH_3 + NO + O_2 => 4N_2 + H_2O$, *or*

$4NH_3 + 2\ NO_2 + O_2 => 3N_2 + 6H_2O$

II. EXPERIMENTAL DETAILS

A. Experimental Systems and Description

The experimental set up consists of single cylinder 4-stroke DI Diesel engine with 80mm bore-diameter, 110mm stroke length, rated speed of 1500rpm, 5 BHP/3.7 KW rated power and water cooled engine.

B. Various Parts of Experimental Setup

1) Kirloskar engine
2) Dynamometer
3) Diesel tank
4) Air filter
5) Three-way valve
6) Exhaust pipe
7) DPF
8) Auto Exhaust Multigas analyser
9) Alternative fuel tank
10) Burette
11) Three way valve
12) Control panel
13) DEF tank with supply module & battery
14) TWC (SCR+DOC)
15) Supply line with dosing module

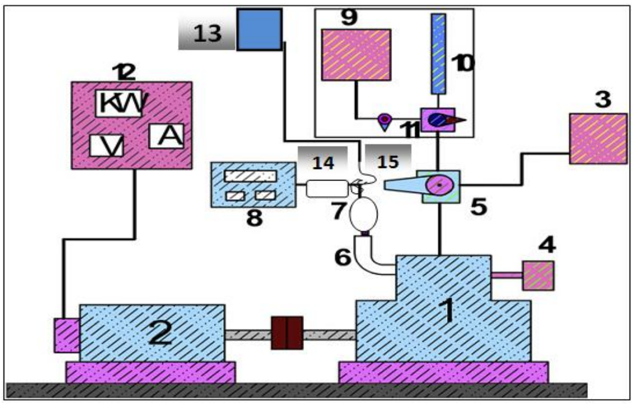

Fig. 3. Allusion Diagram of Experimental Setup

C. Technical Features of modified DEF - system

Dosing quantity	165 g/h @1.8 bar
Atomization	≤400 μm (Sauter Mean Diameter)
Ambient Conditions (with air cooling) Supply Module/tank : Dosing Module :	 $-30.....70^0C$ $-30.....140^0C$
Operating Voltage	12 V
Injection line between Supply Module & Dosing Module (length)	3805 mm
Supply Line Material, Crossection & Varying diameter(s)	Copper , Circular tube & 3mm to 1.5mm
DEF-Tank Material	Plastic
Nozzle Material	Brass
Nozzle Type	Single Hole

D. Experimental Procedure

- Precautions are taken, before starting the experiment on selected engine.
- The engine is started at no load condition.
- After that engine is allowed to run at rated speed of 1500rpm atleast 10 minutes for stabilization.
- The multigas analyzer is prepared to take the required readings of engine emissions.
- Then at 0 KW the probe of the multigas analyzer is placed at the exhaust tail pipe and readings are noted.
- The above experimental procedure is repeated for different loads from no load to 2 KW load, for the same Engine at rated speed of 1500rpm in Three modes as follows:
  i. With-out connecting Diesel Exhaust After treatment system at the end of exhaust tail pipe.

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ii. With catalytic converters (DPF + TWC) connected at the end of exhaust tail pipe.
iii. With catalytic converters (DPF + TWC) and DEF/ Adblue-dosing system connected at the end of exhaust tail pipe.

- After completion of the test, the load on the engine is completely relieved and then the engine is stopped.

III. RESULTS AND DISCUSSIONS

Experiments are conducted when the engine is fuelled with pure diesel. The experiment covered a range of loads. The emission characteristics of the engine are observed in terms of concentration of CO, HC, O_2, NO_x and CO_2. The results obtained for with DPF+TWC converter +DEF system connected at the end of exhaust tail pipe are compared with DPF+TWC converter connected at the end of exhaust tail pipe and without connecting exhaust after treatment system at the end of exhaust tail pipe. The results obtained are represented in the graphical form as follows:

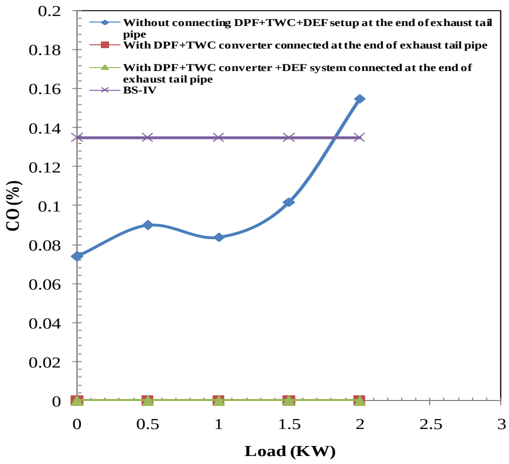

Fig. 4. Load Vs CO

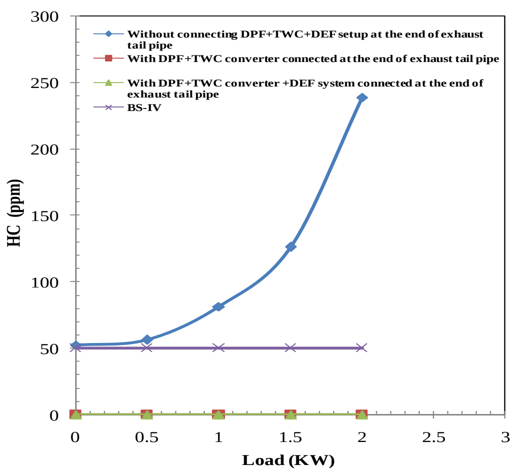

Fig. 5. Load Vs HC

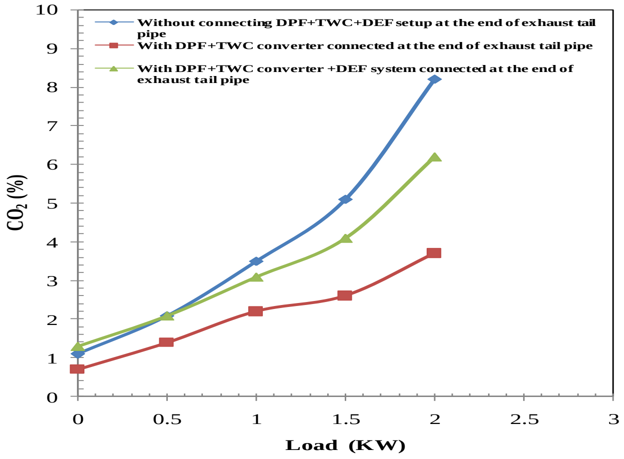

Fig. 6. Load Vs CO_2

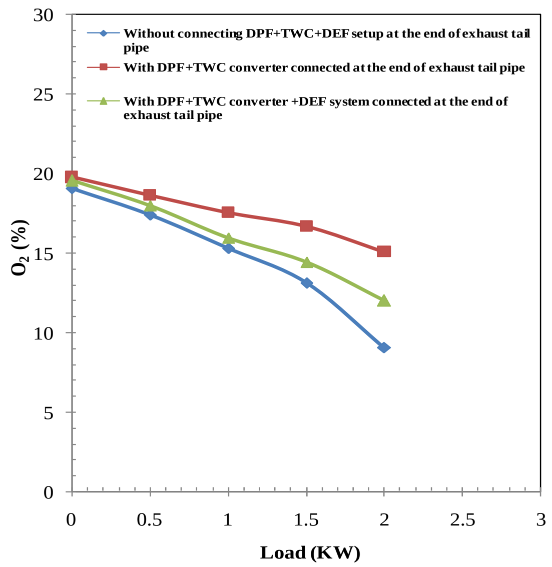

Fig. 7. Load Vs O_2

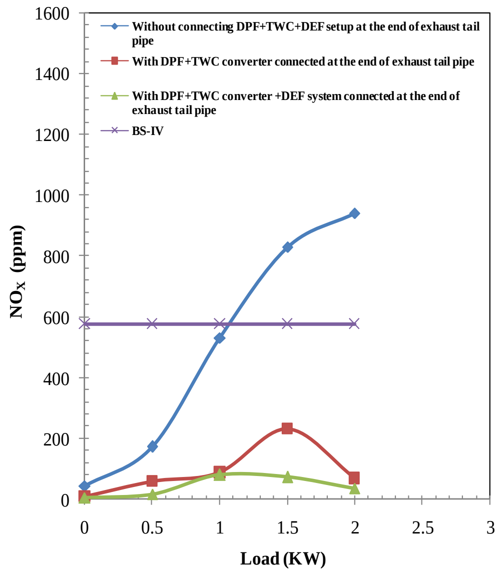

Fig. 8. Load Vs NO_X

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As per the above results, the following conclusion is made for selected diesel engine to meet the diesel engine emissions legislation.

IV. CONCLUSION

From the above analysis the main conclusion is DPF+TWC converter +DEF system is suitable substitute for diesel engine exhaust after-treatment setup as this system produces lesser emission than existing at all loads.

V. ABBREVIATIONS

BS-IV	Bharat Stage-IV (Emission Norms)
DI	Direct Injection
DOC	Diesel Oxidation Catalyst
DEF	Diesel Exhaust Fluid
DPF	Diesel Particulate Filter
SCR	Selective Catalytic Reduction
TWC	Three Way Catalyst

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APPENDIX

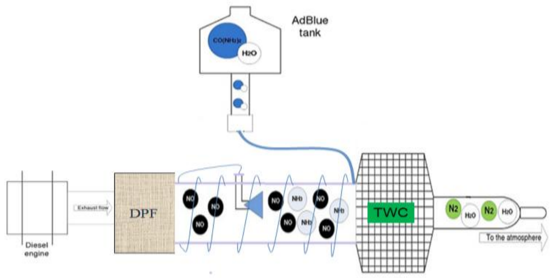

Fig. 9. Schematic Line Diagram of Experimental Setup

Fig. 10. DPF+TWC Converter +DEF Experimental Setup with Engine

Fig. 11. DEF-Supply line with Dosing Module

Fig. 12. DEF-Tank Unit and Auto Exhaust Multigas Analyzer