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Experimentation on Exhaust System Using TWC Converter For Diesel Engine Emissions

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ABSTRACT **:** *We prepared a new kind of exhaust after-treatment system having Diesel Particulate Filter, Three Way Catalytic (TWC) converter (in substitution of SCR & Oxidation catalyst) to determine the scope for enhancing the efficiency of a Three Way Catalytic (TWC) converter system. Our results show that there is a ~99% reduction in the CO and HC emissions after arranging the retrofit. We also found that on an average there is a 72% reduction in the NO_x.*

KEYWORDS : *Diesel engine, DPF, Emissions, SCR, TWC.*

I. INTRODUCTION

The introduction of exhaust gas after treatment systems for diesel engines is a measure to fulfill the legislation requirements [1],[2]. Selective catalytic reduction (SCR) are considered to be promising for this better performance[3]. Therefore, in Europe, on road demonstrations of the SCR systems are conducted[4]. However, there are problems yet to be solved for practical usage of SCR systems. The first one is the low activation for NO_x reduction under low exhaust gas temperatures and transient conditions encountered in real operating conditions.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 reductant [NH_3] added to the exhaust gas is recognized as a flexible remedy for mobile diesel NO_x emission[5],[6]. 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. 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.The present investigation concern with experiment on Diesel engine test-rig inorder to determine the exhaust gas emissions at the end of tail pipe at different loads by arranging the setup proposed.

1.1.Diesel Particulate Filter

The catalyst commonly contains an alumina wash coat supported on a honeycomb shape ceramic brick as shown in below Fig. 1.[7],[8],[9].

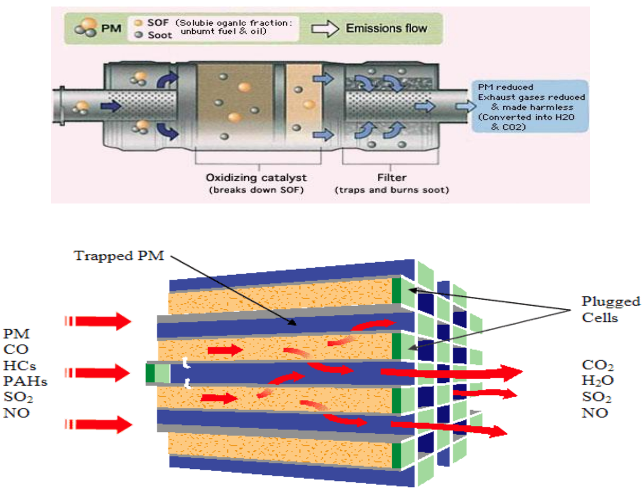
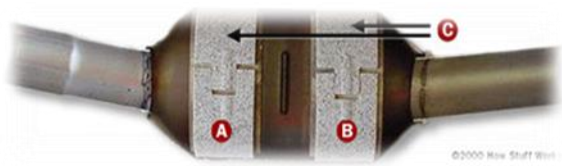


Figure 1: DPF

1.2. 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[10]. The catalyst commonly contains an alumina wash coat supported on a honeycomb shape ceramic brick as shown in Fig. 2. Precious metals are coated onto the alumina[11]. The active part of the catalyst is further divided into oxidation and the reduction catalyst sites[12].

Figure 2: Automotive Catalytic Converter (TWC)



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[13],[14].

A: Reduction Catalyst
B: Oxidation Catalyst
C: Honeycomb Ceramic Structure

<u>Reduction</u> of nitrogen oxides to <u>nitrogen</u> and <u>oxygen</u>:

$2NO_x \rightarrow xO_2 + N_2$

<u>Oxidation</u> of carbon monoxide to carbon dioxide:

Figure 3: Section of TWC

$2CO + O_2 \rightarrow 2CO_2$

Oxidation of unburnt hydrocarbons (HC) to carbon dioxide and <u>water</u>: $C_xH_{2x+2} + [(3x+1)/2]O_2 \rightarrow xCO_2 + (x+1)H_2O$.

II. EXPERIMENTAL DETAILS

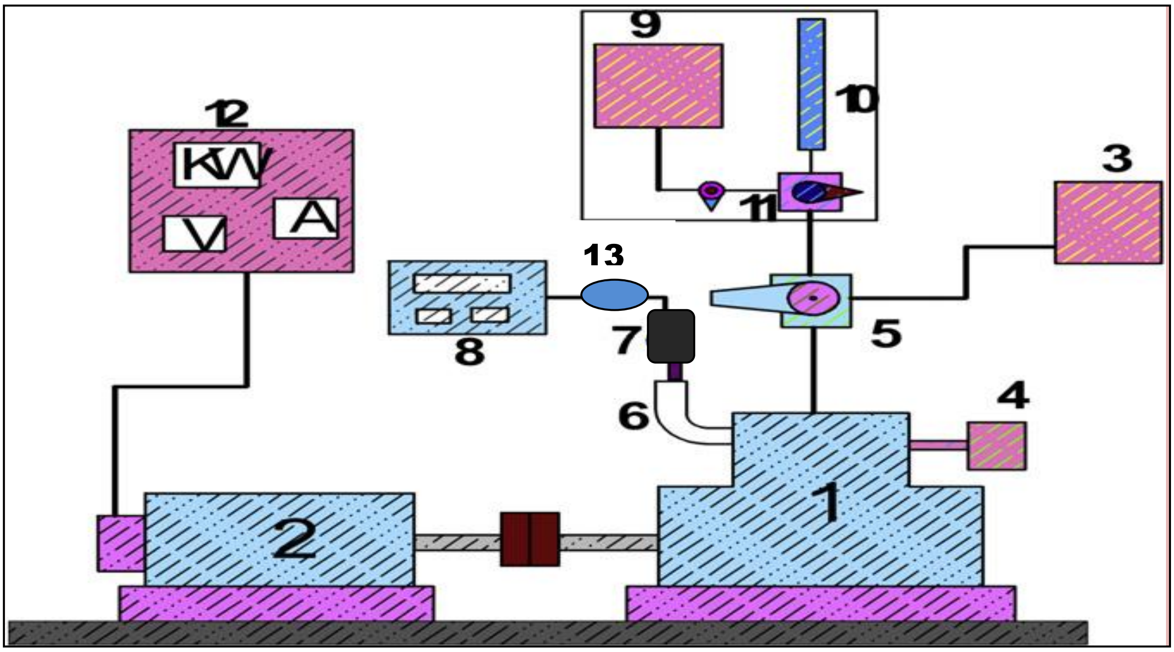
2.1. Experimental Systems and Description

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.

2.2. Various parts of experimental setup {Refer : Fig.4}

1. kirloskar engine
2. alternator/dynamometer
3. alternative fuel tank
4. air filter
5. three-way valve
6. exhaust pipe

7. DPF
8. multigas analyzer
9. diesel tank
10 burrette
11. three way valve
12. control panel
13. TWC (SCR+DOC)



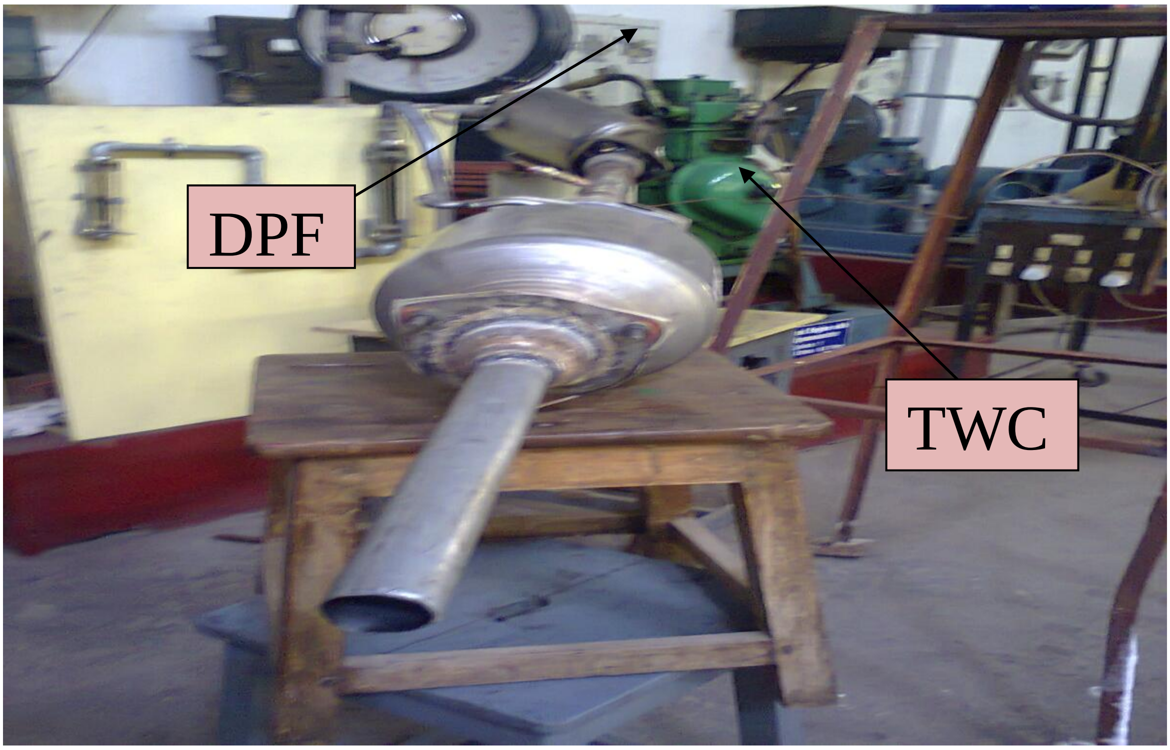


Figure 5:DPF+TWC Converter Experimental Setup with Engine

Figure 6: Auto Exhaust Multigas Analyzer

Figure 7: DPF and TWC Converters

2.3 Experimental Procedure

As first said, pure diesel is allowed to run the engine for about 30 min, so that it gets warmed up and steady running conditions are attained. Before starting the engine, the lubricating oil level in the engine is checked and it is also ensured that all moving and rotating parts are lubricated.The various steps involved in the setting of the experiments are explained below,

- The tests were carried out after installation of the engine testrig with setup
- 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 analyser is prepared to take the required readings of engine emissions.
- Then at 0 KW the probe of the multigas analyser 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

[1] same Engine at rated speed of 1500rpm in Two modes as follows:
[2] With-out connecting Diesel Exhaust Aftertreatment system at the end of exhaust tail pipe.
[3] With catalytic converters (DPF + TWC) connected at the end of exhaust tail pipe.
[4] After completion of the test, the load on the engine is completely relieved and then the engine is stopped.

III. RESULTS AND DISCUSSIONS

Experiments were conducted when the engine was fuelled with pure diesel. The experiment covered a range of loads. The emission characteristics of the engine were 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 were compared with DPF+TWC converter connected at the end of exhaust tail pipe and without connecting catalytic converter at the end of exhaust tail pipe.

Table I: Emission test Results for Pure Diesel (Without connecting catalytic converters at the end of exhaust tail pipe)

S.N0	Load	Speed	CO	HC	CO_2	NO_X	O_2
	kW	rpm	(%)	ppm	(%)	ppm	(%)
1	0	1500	0.074	52	1.1	44	19.08
2	0.5	1500	0.09	56	2.09	173	17.43
3	1.0	1500	0.084	81	3.5	532	15.32
4	1.5	1500	0.102	126	5.1	830	13.15
5	2.0	1500	0.155	239	8.2	942	9.05

Table II: Emission test Results for Pure Diesel (With DPF+TWC converter connected at the end of exhaust tail pipe)

S.N0	Load	Speed	CO	HC	CO_2	NO_X	O_2
	kW	rpm	(%)	ppm	(%)	ppm	(%)
1	0	1500	0	0	0.7	10	19.78
2	0.5	1500	0	0	1.4	60	18.65
3	1.0	1500	0	0	2.2	88	17.54
4	1.5	1500	0	0	2.6	231	16.7
5	2.0	1500	0	0	3.7	69	15.09

As per the above results tabulated the following graphs are drawn.

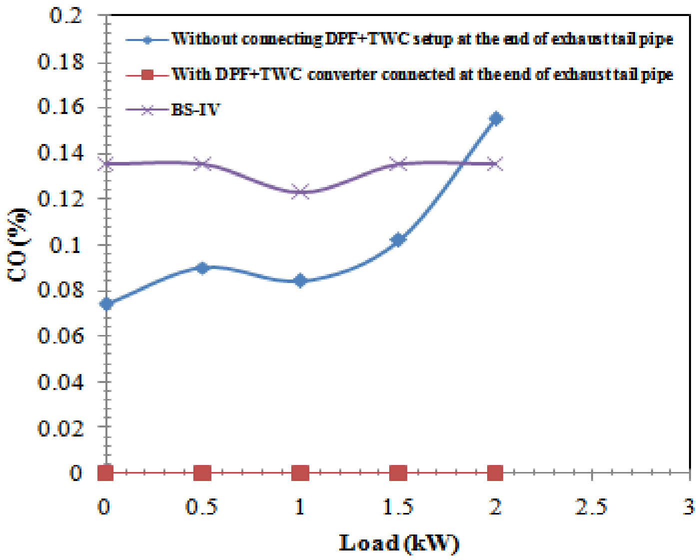


Figure 8:Load against CO

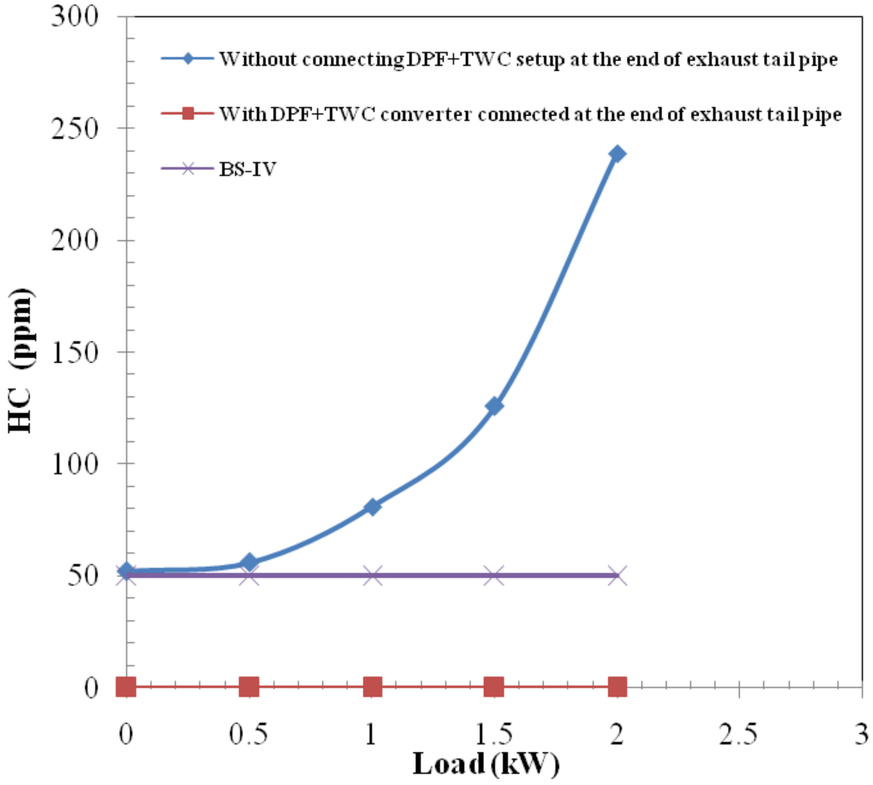


Figure 9: Load against HC

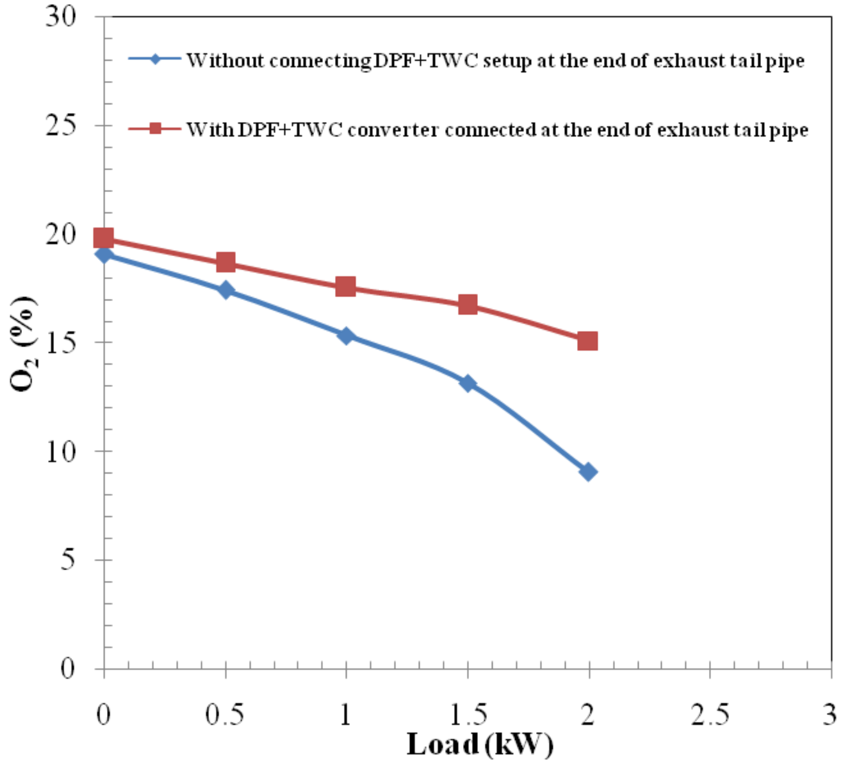


Figure 10: Load against O_2

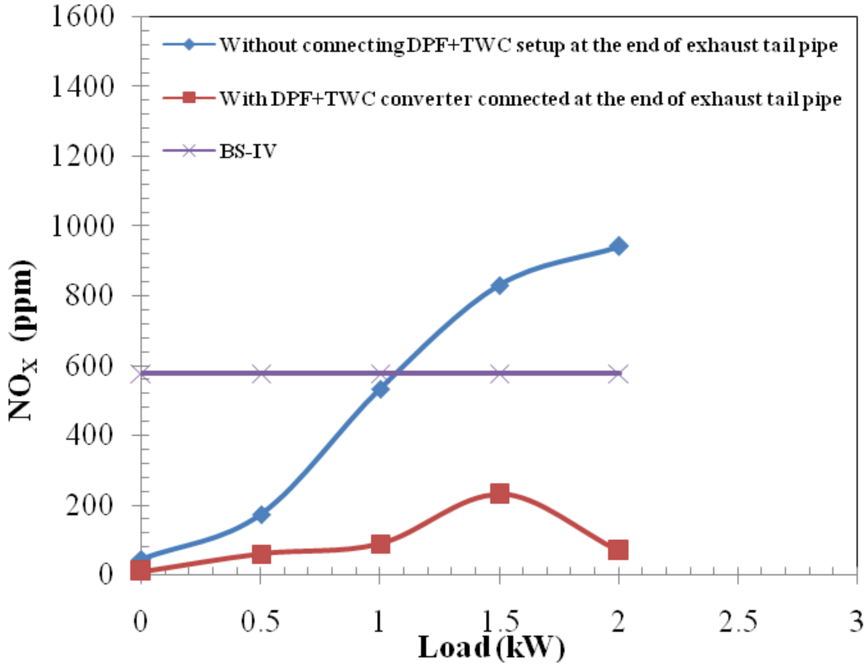


Figure 11:Load against NO_X

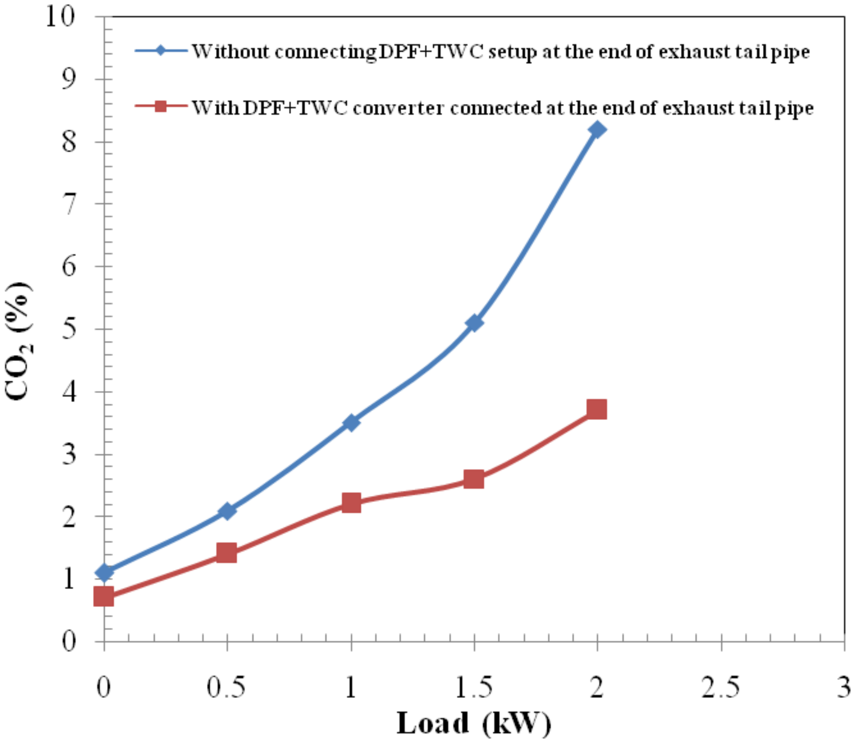


Figure 12: Load against CO_2

As per the above results **obtained** the exhaust after treatment system with DPF+TWC converter is the best suitable for selected diesel engine **to meet the diesel engine emissions legislation**.

IV. CONCLUSIONS

Based on the values obtained for the tests conducted, the following conclusions are made

* CO emission is zero for DPF+TWC converter system connected at the end of exhaust tail pipe when compared without connecting catalytic converter at the end of exhaust tail pipe. The CO emission is lower

when compared to the Bharat stage IV Norms for selected engine at all operated loads with retrofit arranged.

* HC emission is zero for DPF+TWC converter system connected at the end of exhaust tail pipe when compared without connecting catalytic converter at the end of exhaust tail pipe. The HC emission is lower when compared to the Bharat stage IV Norms for selected engine at all operated loads with retrofit arranged.
* Carbon dioxide emission is less for DPF+TWC converter system connected at the end of exhaust tail pipe when compared without connecting catalytic converter at the end of exhaust tail pipe.
* Oxygen concentration is more for DPF+TWC converter system when compared to without catalytic converter system at the end of exhaust tail pipe.
* Nitrogen oxides / dioxides (NO_x) emission is less for DPF+TWC converter system when compared without connecting catalytic converter at the end of exhaust tail pipe. The NO_x emission is lower when compared to the Bharat stage IV Norms for selected engine at all operated loads with retrofit.
* From the above analysis the main conclusion is DPF+TWC converter system is suitable substitute for diesel engine exhaust after-treatment setup as this system produces lesser emission than existing at all loads.

Abbreviations

DI Direct Injection
DOC Diesel Oxidation Catalyst
DPF Diesel Particulate Filter
SCR Selective Catalytic Reduction
TWC Three Way Catalyst

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