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Experimental Study of Emission Improvement on Single Cylinder BSIV Diesel Engine using EGR and After Treatment DOC, POC

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Abstract

This paper describes the experimental study carried on a single-cylinder, direct injection, BSIV diesel engine (8.5 hp @3600 rpm) to obtain the emission reduction up to 10 % margin. The after-treatment devices used to control the emissions is the Exhaust Gas Recirculation (EGR), Diesel Oxidation Catalyst (DOC), and Particulate Oxidation Catalyst (POC). The study has been focused particularly on controlling the NOx and smoke emissions parameters. Three different types of Cat-con have been used for varied catalyst loading, and further, the test carried to measure the smoke reduction to control the Smoke. The test run has been carried on a chassis dynamometer by following the Indian Driving Cycle (IDC). The result shows the maximum conversion of smoke emission for the 20gm loaded converter than the other two Cat-cons. The experimental result shows the decrease in NOx up to 31.30% at higher load and the speed ranging from 2200 to 2600 using EGR, and penalty of percentage increase in the smoke emission because of decrease in the combustion temperature of the cylinder. A Constant Volume Sampling (CVS) system is used for dilute emission measurement of the vehicle along with Catalytic Converter and EGR. Thus, the experiment result shows the marginal improvement of 16.07% and 7.47% for HC+NOx and PM, respectively, has been achieved using Cat-con and EGR.

Keywords — *BSIV Norm, EGR, Catalytic Converter, IDC.*

I. INTRODUCTION

Exhaust Gas Recirculation (EGR) diminishes accessibility of oxygen for the burning of fuel, which brings about generally inadequate combustion and expanded in the particulate issue. Hydrocarbons, carbon monoxide, Smoke are expanded with EGR, yet NOx diminishes essentially. EGR system was seen to be compelling in lessening NO discharges [6]. The 15% EGR rate effectively reduces NOx emission substantially without deteriorating engine performance in thermal efficiency, BSFC, and emissions. At lower loads, EGR reduces NO_x without deteriorating performance and emissions. At higher

Loads increased EGR rate reduces NO_x to a great extent but deteriorates performance and emissions [4]. The results show that applying a high EGR (Exhaust gas recirculation) rate can significantly reduce NO_X emission with an increase in soot emission. However, using a low cetane number fuel could suppress soot emission because it can prolong premixing periods of fuel and in-cylinder gas [7]. A proper injection pattern (an increase of injection pressure and post-injection addition) coupled with a low SR was shown as a suitable strategy to improve the late-cycle diffusion combustion as well as soot oxidation [2]. The increase in CO, HC, and PM emissions can be reduced using exhaust after-treatment techniques, such as Diesel Oxidation Catalyst (DOCs) and soot traps [4].

An exhaust system (casually, "cat" or "con") is a gadget used to decrease the poisonous quality's from an inside combustion engine. Catalytic Converters are most generally utilized as a part of engine vehicle exhaust frameworks. Catalytic converters are additionally utilized on generator sets, Forklifts, mining hardware, trucks, transports, trains, and other engine prepared. Catalytic converters give a domain to a chemical reaction where harmful combustion side effects are changed over to less toxic substances. The LTC strategy to the low compression ratio has led to a PM reduction of about 70% and a NOx lowering of about 80% [3]. When injection timing is retarded, fuel injection starts later. Therefore, incomplete combustion occurs and BTE decreases, and BSFC increases; as lesser output power is produced. Advanced injection timing produces higher cylinder temperature and increases the oxidation process between carbon and oxygen molecules increase NOx emission, thus HC and CO emission decreases [1].

A chassis dynamometer is a device utilized for vehicle testing and advancement. It utilizes a roller to reproduce a street in a controlled condition, as a rule, inside a building. The dynamometers are additionally calibrated for various road load horsepower (RLHP) settings to reproduce the measure of drive required to move a vehicle over a level street surface at 42 km/hr. The engine tried on the testbed is fitted on the vehicle chassis for dilute emission outflow testing. The vehicle is kept running under the Indian Driving cycle, which is said by ARAI. A constant volume sample (CVS) system is the actual mass of particulates present in a given volume of exhaust. In both diesel and gasoline testing, we need to dilute the exhaust with ambient air to prevent water condensation in the collection system. It is necessary to measure or control the total volume of exhaust plus dilution air and collect a continuously proportioned volume of the sample for analysis [14].

II. SPECIFICATION OF EXPERIMENTAL ENGINE

The specification of the test engine used for the present work is given in Table I as follow

TABLE I
Specification of Engine

Working Fluid	BS4 Diesel
Number of Cylinder	1
No. of Stroke Per Cycle	4
Engine Name	Single Cylinder Diesel Engine
Bore	86 (mm)
Stroke	75 (mm)
Dry Weight	52 kg
Intake System	Naturally Aspirated
Metering System	Direct Injection
Compression Ratio	19.5
Displacement	435 (cm^3)
Maximum Torque	18 Nm @ 2400 rpm
Rated Power	8.5hp @ 3600 rpm

III. EXPERIMENTAL WORK

A. EGR Setup

In old EGR system uses vacuum regulated valve, while that of new EGR system uses electronic control unit (ECU) to control exhaust gas recirculation. The ECU output depends on namely:

Throttle Position sensor: Throttle position is sensed by the throttle position sensor (TPS). The throttle position sensor (TPS) is mounted on the throttle shaft.

Flywheel mounted alternator (FMA) Sensor: Engine speed is detected by the attractive FMA sensor which is mounted on the ringer lodging of the flywheel. At the point when the engine is idling, the EGR valve is shut and there is no EGR stream into the manifold. The EGR valve stays shut until the point when the engine is warm and is working under load. As the load increments and combustion temperatures begin to rise, the EGR valve opens and begins to spill deplete over into the intake manifold. This has an extinguishing impact that brings down burning temperatures and reduces the development of NOx.

According to the literature the exhaust gas temperature is decreased with EGR and HC, CO, and Smoke are increased with EGR but NOx emission decreased significantly, EGR can be applied to diesel engine without sacrificing its efficiency and fuel economy, and NOx reduction can thus be achieved [5].

The EGR system mapping has been carried out on the EGR tuning software, and the results displayed by the software, as shown in fig.1. The mapping result shows the TPS vs. speed graph. This EGR map shows the position of the throttle in terms of percentage and engine speed in RPM. The throttle position sensor and EGR valve are connected to ECU. ECU senses the signal from tuning software, and TPS decides the EGR position. The ECU is programmed for mapping of 65 % opening of EGR valve. The result from the map provides the % opening of the EGR i.e., when the engine is running at 2200 RPM, and the throttle position opening is at 60 %, then the mapping table shows the EGR opening of 65 %. For e.g. at idle engine speed the EGR valve is 100% open (i.e. at 0% throttle) and at 100% throttle the EGR is 0% open (i.e. 100% closed).

B. Use of Diesel Oxidation Catalyst (DOC) and Particulate Oxidation Catalyst (POC)

Loading of catalyst: Loading of catalyst can be characterized as the catalyst shown in the professional surface's 1 cubic foot. This surface is normally a honeycomb-like structure made up of base metal, generally aluminum, and is stacked with uncommon metals like Platinum, Palladium, rhodium, and so on. This catalyst helps influence these responses to occur at a lower temperature, which occurs at a high temperature.

There are three different types of the catalytic converter has been used by varying catalyst loading and also materials;

1) Cat-con 1:

The first catalytic converter used DOC+ DOC. This catalytic converter has used precious metals platinum, palladium, and rhodium. This metal has a ratio of 1:0:0. Platinum is used as a reduction catalyst, and as an oxidation catalyst, loading is 10gm+5gm and metallic material is used in this catalytic converter.

2) Cat-con 2:

This is the second type of catalytic converter used. This cat-con is DOC+POC type that means diesel oxidation catalyst and particulate oxidation catalyst. This catalytic converter has precious metal ratio pt: pd: rd as 1: 0: 0, and loading is 15gm+0gm, the metallic material is used.

3) *Cat-con 3:*

This is the third catalytic converter used from the lot. This catalytic converter is DOC+POC. This Catalytic converter has precious metal pt: pd: rd ratio as 1:0:0 and loading is 20gm+0gm. The material used is ceramic support or monolith of oval cylindrical shape with a structure made up of multiple cell in a panel.

0	1000	1300	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3850	4000	RPM
10	75	75	65	65	65	65	65	65	65	65	65	65	65	65	65	65	
20	75	75	65	65	65	65	65	65	65	65	65	65	65	65	65	65	
30	75	75	65	65	65	65	65	65	65	65	65	65	65	65	65	65	
40	75	75	65	65	65	65	65	65	65	65	65	65	65	65	65	65	
50	75	75	65	65	65	65	65	65	65	65	65	65	65	65	65	65	
60	75	75	65	65	65	65	65	65	65	65	65	65	65	65	65	65	
70	75	75	65	65	65	65	65	65	65	65	65	65	65	65	65	65	
80	75	75	65	65	65	65	65	65	65	65	65	65	65	65	65	65	
90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

TPS

Fig 1: Map of % opening of EGR valve

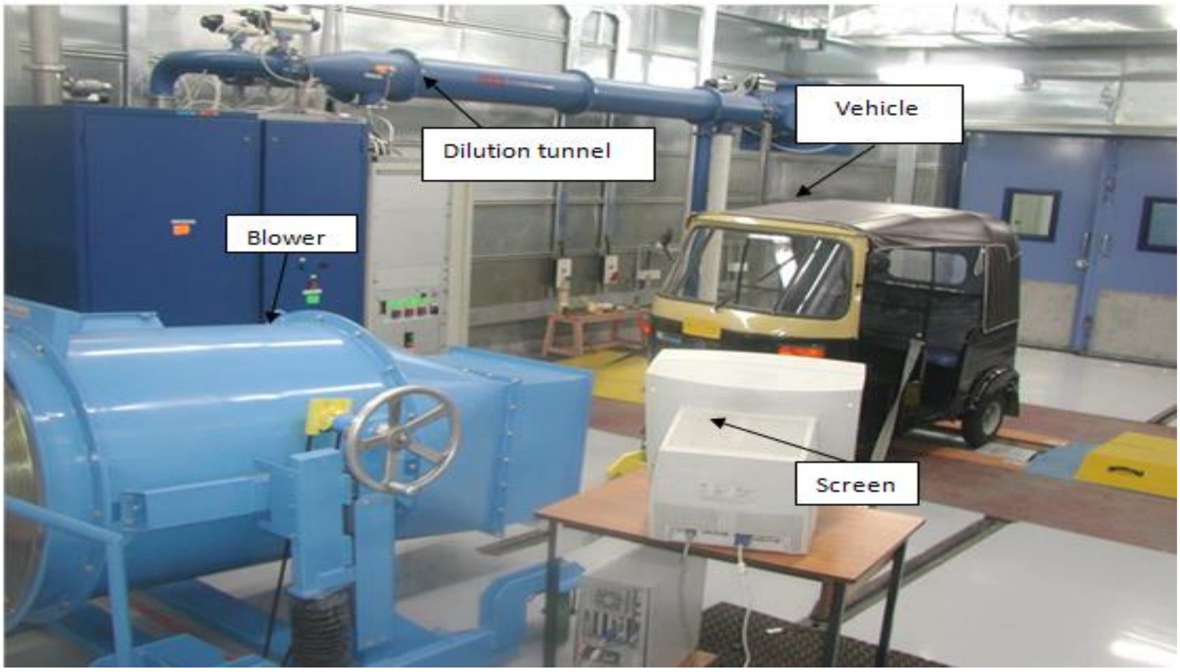

Fig 2: Vehicle emission testing on chassis dynamometer

C. Indian Driving Cycle

The three-wheeler is tried on chassis dynamometer under Indian driving cycle as appeared in the fig. 2. The test setup comprises of Blower, Dilution burrow, Screen for following Indian Driving Cycle. In India, the first Indian driving cycle (IDC) created by ARAI in the mid-90s has been utilized for portraying the mass discharges of two and three wheelers while another cycle called changed Indian driving cycle appeared in fig 3, is utilized for traveller autos, which is the same as the European driving cycle with an adjustment of the greatest speed of the last period of the cycle. It comprises of six indistinguishable cycles in which speed and pattern of gear changing is same. The detail of as for time versus speed is given with graph after broad street tests by the researchers at the automotive research association of India, Pune, when the mass outflow standards appeared. Since the IDC includes excessively numerous drifters as a result of aimless activity circumstances in India, this is currently taken after for two/three wheelers, which are normal methods of transportation in Indian urban communities. The IDC comprises of Cold begin with 40 sec sitting, 6 cycles comprises of 108 sec each. Add up to test time 648 sec. Add up to test Distance 3.948 km. Max speed 42km/hr. The IDC comprise of 16 sec of Idling time between each cycle.

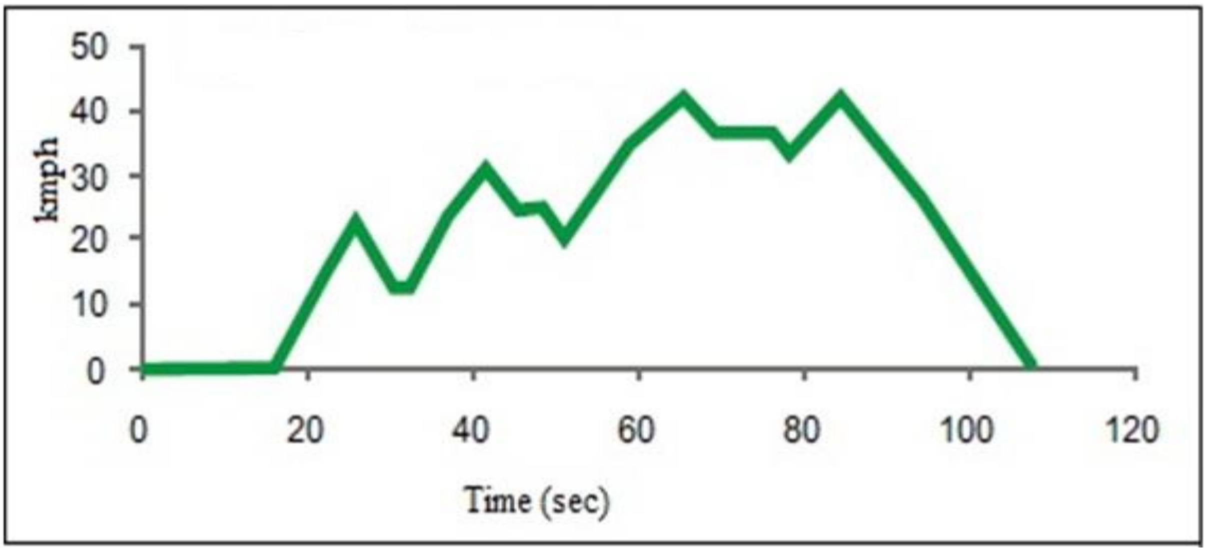

Fig 3: Indian Driving Cycle

IV. RESULT AND DISCUSSION

In this section first, NO_X emission improvement of single cylinder diesel engine achieved by using EGR. Second, smoke emission improvement achieved by using three different types of catalytic converter by varying catalyst loading and materials.

A. Effect of using EGR with 65% map

Smoke

It is observed that smoke values increased by 51.09% at higher load and the speed ranging from (2200 to 2600 rpm) with EGR, when compared with no EGR. Hence, the smoke value increased when the EGR is used & vice versa. The reason behind that is the availability of oxygen for combustion is reduced which results in incomplete combustion, which leads to formation of more particulate matter than usual.

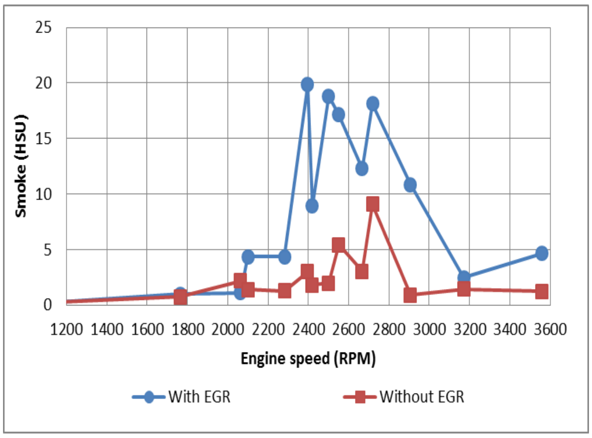

Fig 4: Smoke (HSU) V/s Engine speed (rpm)

NOx (Oxides of Nitrogen)

In every engine speed and load condition stages mainly considered to reduce NOx. The NOx emissions reduced drastically by 31.30% at high load engine speed (2200rpm-2600rpm) with EGR. By using EGR reduction of NOx takes place lower oxygen concentration and fairly low flame temperatures in the combustible mixture.

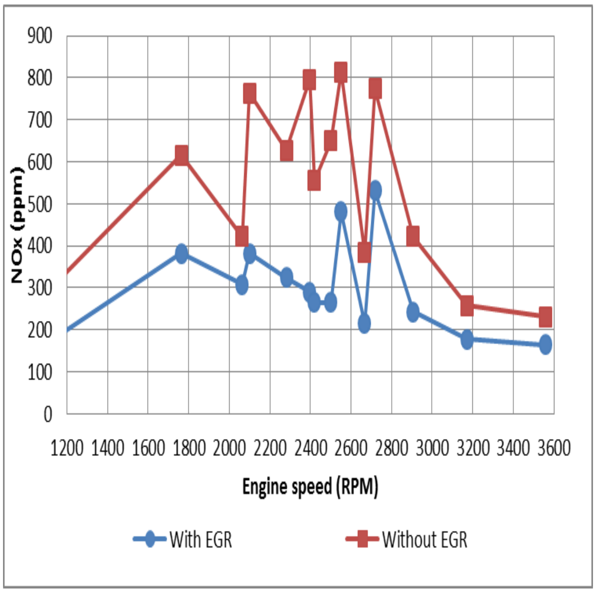

Fig.5: NOx (ppm) V/s Engine speed (rpm)

B. Effect of using three different catalytic converters

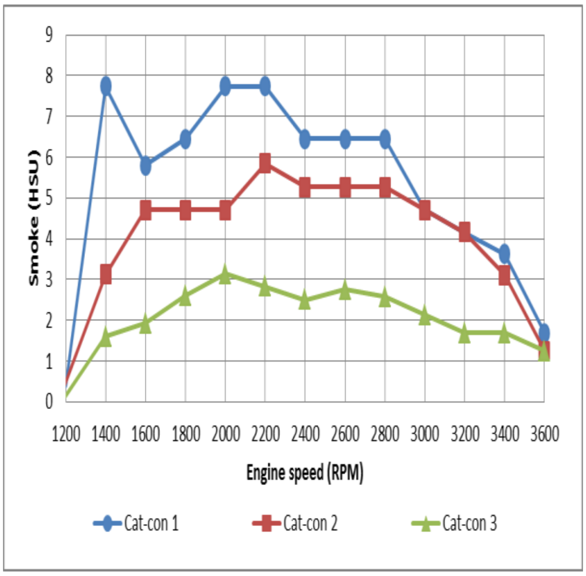

Fig.6: Smoke (HSU) V/s Engine speed (rpm)

The fig. 6 shows graph of the Smoke V/s Engine speed (rpm) and its results discussed below,

- Cat-con 1 (DOC+DOC) loading (10+5gm) and substrate of metallic material it gives 7-8 HSU. This Cat-con is unable to perform efficiently.
- Cat-con 2 of (DOC+DOC) loading (15+0gm) of metallic material shows reduction of smoke value 26.88% compared to Cat-con 1.
- Cat-con 3(DOC+POC) loading (20+0gm) of with ceramic material shows reduction of smoke value up to 55.15% compared with Cat-con 2.

a) Vehicle Emissions

Since from all above modification experimental graphs it can be conclude that the changes are made the reduction or improvement the Smoke and NO_X raw emission values. Thus after getting better performance and raw emission this engine will be mounted on the vehicle and run on chassis dynamometer shown in fig. 2 with Indian Driving Cycle. Since on vehicle, the implementation of Cat-con 3 DOC+POC (20gm+0gm.) loading will be provided to the after exhaust pipe.

On Indian Driving Cycle, at that point the test emission will be taken in the gas analyser and last outcomes will be shown on the PC with the discharge emission and with the warning whether vehicle is passed in BS IV restrains or not likewise computing margin (%) improvement values. The drivability on the chassis dynamometer, control at wheel likewise can be performed. Be that as it may, for this situation the change of BS IV emission standards is vital, the emanation test performed for looking at BS IV standards. The vehicle exhaust emission test on chassis dynamometer is as take after;

TABLE II
Vehicle Exhaust Emissions after Testing On Chassis Dynamometer

BS IV Limits	Emission	Mass (g/km)	Margin (%)
0.345	CO	0.131	62.10
	HC	0.031	
	NO_X	0.288	
0.380	HC+NO_X	0.319	16.07
	CO_2	79.01	
0.0354	PM	0.0328	7.47
RESULT			
Passed in all for BS IV Limits			
	Test Validity	Valid	
	Result	Ok	

V. CONCLUSION

The single cylinder, direct injection, BSIV diesel engine has been tested to reduce the emission by 10 % margin by using the after treatment devices such as EGR and the three different Catalytic Converter of varied loading of the catalyst. The test result concludes the beneficial of using the EGR system for achieving the NO_X emission reduction. In this test, the NO_X is decreased by 31.30% compared to earlier emissions which were taken without EGR. Increase in the EGR %, decreases the NO_X as the combustion temperature get decreases with penalty of increased Smoke. Amongst the three developed Cat-con, the Cat-con 3 has found to be the most effective catalytic converter compared to other two converters, also the Smoke has been reduce by 55.15% compared with Cat-con 2. Thus, the Cat-con 3 is the most preferable catalytic converter. Vehicle exhaust emissions after testing on chassis dynamometer has achieved margin on BS IV norms for ($HC+NO_X$) by 16.07% and PM by 7.47%.

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