Effect of Injecting Urea and DEE Solution at Exhaust Pipe of Diesel Engine with DPF and DOC

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Abstract: **In the present investigation, post combustion techniques are adopted for existing diesel engine to reduce the emissions. Two after treatment devices viz; diesel particulate filter (DPF) and diesel oxidation catalyst (DOC) were fixed at exhaust pipe of engine; and urea solution and Di-Ethyl Ether (DEE) are injected separately. Experiments were conducted on a four stroke single-cylinder, water cooled compression ignition engine. All tests were conducted at different loads viz. 4kg and 6kg load. The engine speed is maintained constant at 1380 rpm. Diesel engine has bore 80mm, stroke 110mm, running at 1380 rpm has compression ratio 16:1, rated power 3.68 KW. CO emission reduced by 36% combining DPF, DOC and injecting urea solution. NO_x emission reduced by 15% when DPF and DOC are combined and reduced by 30% when urea solution is injected. HC emission reduced by 9% when DEE is injected in exhaust pipe with DPF and DOC. Overall comparison of all the results, it can be concluded that the least emission level was observed when engine is operated at 4kg load and having combined DPF, DOC and injecting urea solution. At this condition, the emissions values are CO 0.5%, HC 53 ppm, NO_x 446 ppm. Hence, there is need for combined DPF, DOC and urea solution injection at the exhaust pipe for an existing diesel engine.**

Keywords: **Diesel Engine, Urea solution, Di Ethyl Ether, Diesel particulate filters, Diesel oxidation catalyst.**

I. INTRODUCTION

Diesels are the most versatile fuel-burning engines in common use today. They are simpler, more efficient, more economical and safer, because diesel fuel is less volatile and vapour less explosive than other fuels. Pollution is one of the biggest drawbacks of diesel engines. They are noisy and they produce many unburned pollutants like Nitrogen Oxides (NO_x), Carbon Monoxide (CO), Hydrocarbons (HC), Particulate Matter (PM), Carbon Dioxide (CO_2), Sulphur Dioxide (SO_2), aldehydes most harmful pollutants of diesel engine. Carbon and hydrogen construct the origin of diesel fuel. Vertin *et al*. [1] conducted a comprehensive investigation of B20 impacts on cordierite DPFs. They blended soy-based methyl ester biodiesel with ultra-low sulfur diesel fuel, and ran dynamometer tests to generate results. PM emissions were reduced 20% with B20 in transient tests, but were similar in steady state tests, indicating PM differences are cycle dependent. There is minor improvement in passive NO_2 regeneration with B20. No deterioration in catalyst performance was observed after 120 active regenerations. Mayer *et al.* [2] evaluated four types of partial filters that are reported to have 30-50% filtration efficiency. In a retrofit light-duty diesel application, they found the best filtration efficiency with one type was indeed 63%. However, under critical but realistic conditions filtration of the others measured substantially lower than the expected 30 %, depending on operating conditions and prior history, and could even completely fail. Ntziachristos *et al.* [3] Due to the stringent emission standards set worldwide, particulate matter (PM) emissions from diesel vehicles have seen significantly curtailed in the last decade, and are expected to be reduced even further in the future. This paper addresses these issues comparing the characteristics of particle emissions from a current diesel passenger car, gasoline one and two small two-wheelers. Abdul-Khalek *et al.* [4] in their work, exhaust particle number concentrations and size distributions were measured from the exhaust of a direct injection of the diesel engine. Conventional dilution tunnel systems have much slower dilution processes making more time available for nucleation and growth. Thus, it is likely that if this engine were tested in such a system, materials that are more volatile would be present in the nuclei mode and its mass, and possibly number, concentrations would be greater.

Johnson T V *et al*. [5] this paper will review the field of diesel emission control with the intent of highlighting representative studies that illustrate the state-of-the-art. First, the author reviews general technology approaches for heavy and light duty applications. Finally, system integration examples are provided. Majiewski A *et al.* [6] suggested that diesel particulate filters capture particle emissions through a combination of filtration mechanisms, such as diffusional deposition, inertial deposition, or flow –line interception. Collected particulates are removed from the filter, continuously or periodically, through thermal regeneration. Diesel filters are highly effective in controlling solid particulate emissions – including solid particle numbers – but may be ineffective in controlling liquid fractions of PM emissions. Filters were first commercialized as retrofit devices, followed by a wide scale adoption on new light –duty and heavy-duty diesel engines in both highway and non-road applications.

Miss Chaitali A. *et al.* [7] in their paper stated that many techniques now exist for the image compression and much effort is being expended in determining the optimum compression transforms. Various techniques of data compressions are available but mostly compression is done using cosine and wavelet transforms. In this paper also focused on the two technologies of image compression are highlighted and they are lossy compression, lossless compression and various technology included in them. Compression of the digital image data is the image compression process. Majeiwiski A *et al.* [8] urea –SCR technology has been adopted as a NO_x reduction strategy from mobile diesel engines. The application of SCR is more cost effective that the competing technologies, High NO_x reductions depend on the catalyst temperature window and on the urea injection control strategy, which remains a challenge under transient operating conditions.

Majeiwiski A *et al.* [9] in the Selective catalytic reduction (SCR) process, NO_x reacts with ammonia, which is injected into flue gas stream before the catalyst. Different SCR catalyst such as Vanadium oxide or metal substituted zeolites have different operating temperature windows and must be carefully selected for a particular SCR process. Ammonia SCR has been used in the industrial processes, in stationery diesel engines, as well as in some marine engines has been adopted for mobile diesel engines in both heavy and light duty applications.

Thompson N *et al.* [10] paper presents an overview of the results on heavy duty engines collected, which aimed at the characterization of exhaust particle emission from road vehicles. Measurements were made in three labs to evaluate a wide range of particulate properties with a range of heavy-duty engines and fuels. The measured properties included particle number, with focus separately on nucleation mode and solid particles, and total mass.

II. EXPERIMENTAL SETUP

Experiments were conducted on a four-stroke single-cylinder, water-cooled compression ignition engine. The specifications of the diesel engine are shown in the table 1. The measuring of fuel consumption (For diesel), speed and emissions has been recorded manually. All tests are conducted at different loads viz, no load, 4kg and 6kg load. The engine speed is maintained at 1380 rpm. After every load, the engine is allowed to attain steady state for duration of about 15 minutes. The specification of DPF and DOC has been in table 2 and 3 respectively. The properties of Urea solution and DEE have been shown in table 4 and 5. Fig. 5 shows the 4-Stroke Single Cylinder Diesel Engine used for the test runs. The photograph of DPF and DOC has been shown in Fig. 2 and 3 respectively. Fig. 4 shows urea solution and DEE used for injecting at the exhaust pipe of a diesel engine.

Fig. 1: Diesel Engine with DPF, DOC and injecting Diesel Exhaust Fluid

Fig. 2: Photograph of Diesel Particulate Filter

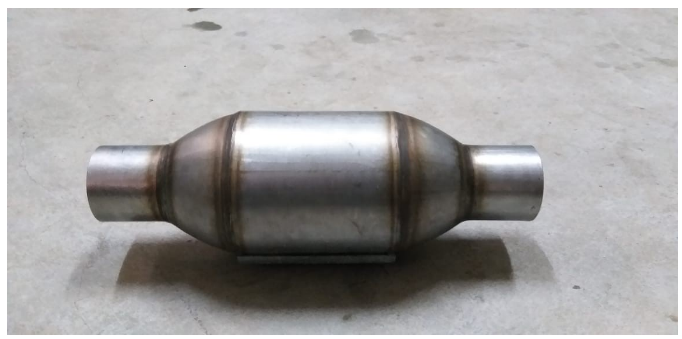

Fig. 3: Photograph of Diesel Oxidation Catalyst

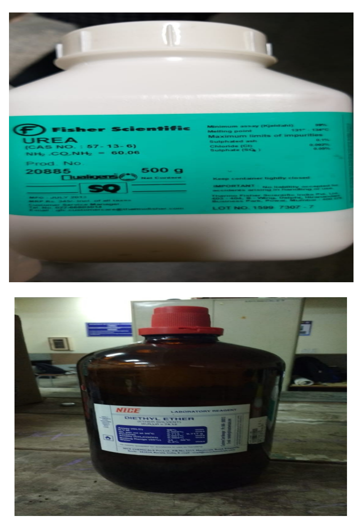

Fig. 4: Photograph of Urea solution and DEE fluid use

Table 1. Specifications of Diesel Engine

Type of Ignition	CI
No. of Cylinders	1
Rated Power	3.68 KW
Rated Speed	1500 rpm
Bore x Stroke	80 mm x 110 mm
Compression ratio	16:1

Table 2: Specifications of Diesel Particulate Filter

DPF core	150mm X 150mm
Volume	2 Liter
Cell Density	100 cpsi
Material	Cordierite
Chemical Composition	Al_2O_3 35.2 ±1.5% SiO_2 50.9±1.5% MgO 13.9±1.5%
Compressive Strength	≥ 10 Mpa
Porosity	≥45%
Maximum Use Temperature	≥1200°C
The average of pore diameter	7-10μm
Can thickness	1.2 mm
Total Length	400 mm
PGM	15g/ft Pt/Pd=3/1
PGM loading	15gm/ft3

Table 3: Specifications of Diesel Oxidation Catalyst

Cell Density	400cpsi
Material	Cordierite
Total Length	320 mm
Volume	2 Liter

Table 4: Properties of Urea solution

Odour	Slight ammonia scent
Density	1.33 g/cm^3
Specific gravity	1.33 at 25^0C 1.225 at 132.7^0C
Viscosity	2.58 cp at 132.7^0C
Melting point	132.7^0C
Specific heat at 25^0C	0.321 Kcal/ Kg^0C

Table 5: Properties of DEE

Molecular Weight	74.14 gm/mol
Freezing point	-116^0C
Boiling point	35^0C
Density at 20^0C, g/mL	0.71
Colour	Colourless
Flash point	-45^0C

III. RESULTS AND DISCUSSIONS

This section explains the performance and emissions of the diesel engine operated on diesel with when DPF, DOC were positioned and urea solution and DEE are injected at exhaust pipe. In all test runs, measurement of emissions has been done before gases are let to the atmosphere.

A. Performance parameter

Brake thermal efficiency of diesel engine without devices and with devices and fluid injection in exhaust pipe of diesel engine at 4Kgs and 6Kgs loads are shown in Fig. 5. From Fig. 1, it can be seen that the brake thermal efficiency at 4Kg without devices is found to be 14.75% and remains unchanged with devices and fluid injection in exhaust pipe of diesel engine. At 6kg loads, the brake thermal efficiency without devices is found to be 21.45% and remains same with devices and fluid injection in exhaust pipe of diesel engine.

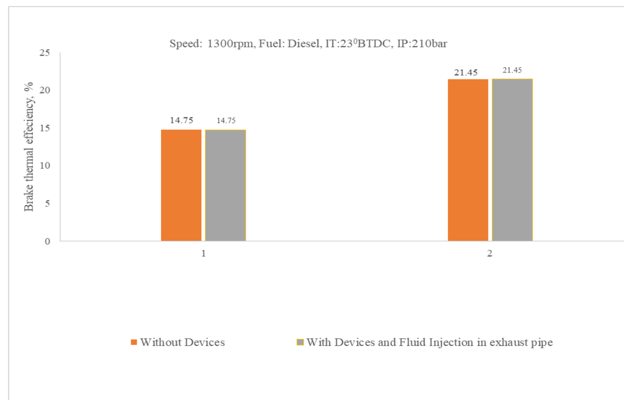

Fig. 5: Brake thermal efficiency with or without after-treatment devices

B. Effect of Urea Solutions on emissions

B.1 HC emissions

HC emissions for two loads when the engine is fuelled with diesel and adopted with DPF, DOC and Urea solution injection in exhaust pipe as shown in Fig. 6. As per reading recorded on engine at both the loads, HC emission increased while using DPF by 12% and when urea solution is injected with DPF, it further increased by 23% [1]. However, HC emission decreased with DOC; further by 11% when urea solution injected with DOC, HC Emission reduced by 8%. Meanwhile, HC emission reduced by 2% when urea solution is injected in exhaust pipe with DPF and DOC [1, 6]. Hence, utilizing only DPF is not advisable and combination of both DPF, DOC and urea injection is essential for such engine operation. Having these combined DPF, DOC and urea solution injection, overall reduction in HC is less as compared to that of existing diesel engine; the values are 58 and 43 ppm respectively.

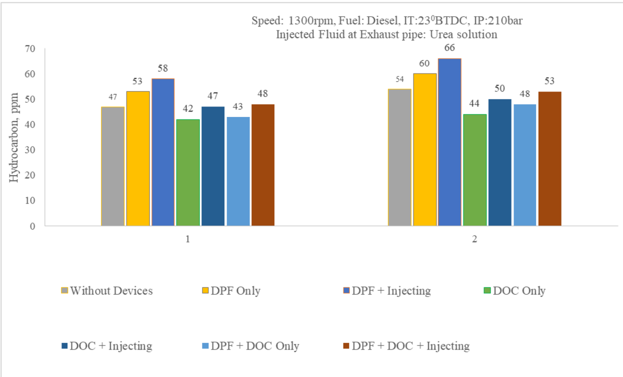

Fig. 6: HC emission at 4Kg and 6Kg loads for injection of Urea solution

B.2 CO emission

CO emissions for two loads when the engine is fuelled with diesel and adopted with DPF, DOC and Urea solution injection in exhaust pipe as shown in Fig. 7. For both the loads, CO emission increased when using DPF by 11% and when urea solution is injected with fixed DPF, it increased by 1%. CO emission decreased with DOC by 47% and when urea solution injected with DOC, CO emission reduced by 50%. It may be due to ammonia reacting with CO and reducing CO emission. During this reaction, the heat released may cause the CO_2 to split into CO and O_2, which further reacts with ammonia, and hence the CO_2 is reduced by injecting urea[1]. However CO emission reduced by 36% combining DPF and DOC; injecting urea solution along with DPF. Hence, utilizing only DPF is not advisable and combination of both DPF, DOC and urea injection is essential for such engine operation. The CO emission has decreased from 0.85% to 0.5% when this combination is adopted while running the engine at 6kg load.

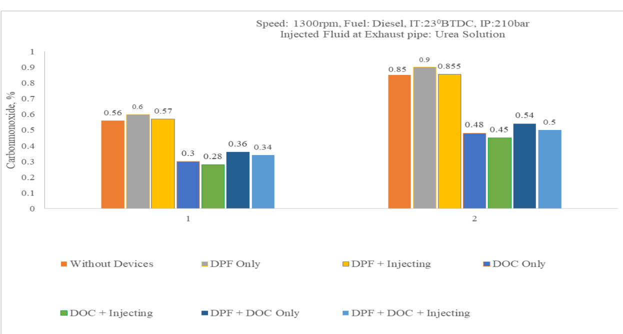

Fig. 7: CO emission at 4Kg and 6Kg loads for injection of Urea solution

B.3 NO_x emission

NO_x emissions for two loads when the engine is fuelled with diesel and adopted with DPF, DOC and Urea solution injection in exhaust pipe as shown in Fig. 8. NO_x emission decreased when using DPF by 10% and further injecting urea solution, NO_x emission reduced by 29%[25]. NO_x emission decreased with DOC further by 5% and further by injecting urea solution, NO_x emission decreased by 25%. As the urea in the form of ammonia reacts with the exhaust gas and reduces its temperature leads to reduction in NO_x emission. However, NO_x emission reduced by 15% when DPF and DOC are combined and reduced by 30% when urea solution is injected in exhaust pipe. Hence, utilizing only DPF is not advisable and combination of both DPF, DOC and urea injection is suggested for better engine operation.

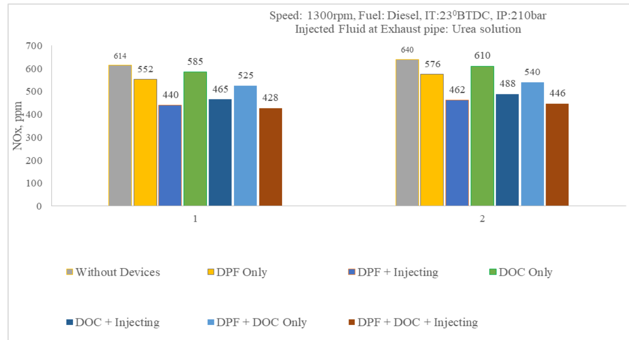

Fig. 8: NO_x emission at 4Kg and 6kg loads for injection of Urea solution

C. Effect of DEE on emissions

C.1 HC emissions

HC emissions for two loads when the engine is fuelled with diesel and adopted with DPF, DOC and DEE injection in exhaust pipe as shown in Fig. 9. As per reading recorded on engine at both the loads, HC emission increased while using DPF by 12% and when DEE is injected with DPF, it further increased by 34%. However, HC emission decreased with DOC further by 11% and when DEE injected with DOC HC Emission reduced by 4%. Meanwhile, HC emission reduced by 9% when DEE is injected in exhaust pipe with DPF and DOC. Hence, utilizing only DPF is not advisable and combination of both DPF, DOC and DEE injection is essential for such engine operation. Having these combined DPF, DOC and DEE injection, overall reduction in HC is less as compared to that of existing diesel engine; the values are 50 and 53 respectively.

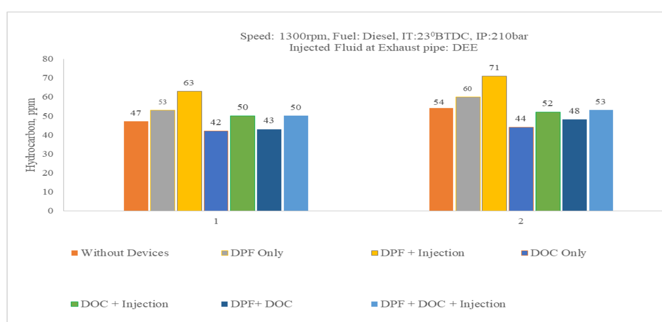

Fig. 9: HC emission at 4Kg and 6Kg loads for injection of DEE solution

C.2 CO emission

CO emissions for two loads when the engine is fuelled with diesel and adopted with DPF, DOC and DEE injection in exhaust pipe as shown in Fig. 10. For both the loads, CO emission increased when using DPF by 7% and when DEE is injected with fixed DPF, it decreased by 9%. CO emission decreased with DOC further by 47% and when DEE injected with DOC, CO emission reduced by 56%. However CO emission reduced by 36% combining DPF and DOC; injecting DEE along with DPF and DOC CO reduced by 47%[14]. Hence, utilizing only DPF is not advisable and combination of both DPF, DOC and DEE injection is essential for such engine operation. The CO emission has decreased from 0.85% to 0.46% when this combination is adopted while running the engine at 6kg load.

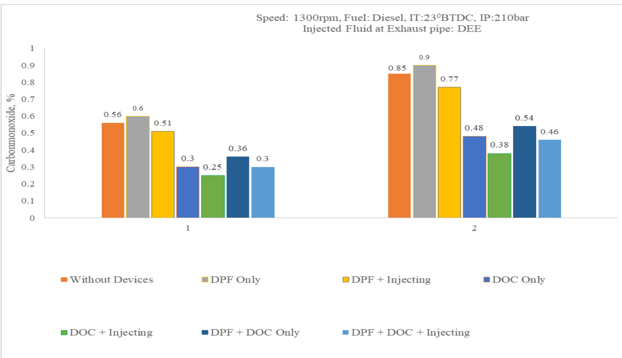

Fig. 10: CO emission at 4Kg and 6Kg loads for injection of DEE solution

C.3 NO_x emission

NO_x emissions for two loads when the engine is fuelled with diesel and adopted with DPF, DOC and DEE injection in exhaust pipe as shown in Fig. 11. NO_x emission decreased when using DPF by 11% and further injecting DEE, NO_x emission reduced by 18%.NO_x emission decreased with DOC further by 5%. and further by injecting DEE at this condition, NO_x emission decreased by 13% [2]. However, NO_x emission reduced by 15% when DPF and DOC are combined and when DEE is injected in exhaust pipe the NO_x emission was reduced by 22%. Hence, utilizing only DPF is not advisable and combination of both DPF, DOC and DEE injection is suggested for better engine operation.

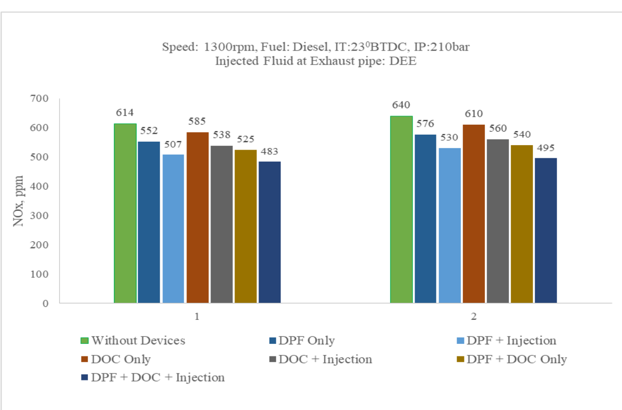

Fig. 11: NO_x emission at 4Kg and 6kg loads for injection of DEE solution

D. Overall comparison

The overall comparison of HC emissions without and with injecting of urea solution and injecting DEE is as shown in Fig. 12. There is a reduction in HC level from 60ppm to 48ppm during the test run of without fluid injection and 66ppm to 53ppm when urea solution is injected; 71ppm to 53ppm when DEE is injected at 6kg loads.

Fig. 12: Overall Comparison of HC emissions

The overall comparison of carbon monoxide without and with injecting of urea solution, and DEE is as shown in Fig. 13. There is a reduction in CO level from 0.9% to 0.54% during the test run of without urea solution injection and 0.855% to 0.5% when urea solution is injected. Meanwhile, when DEE is injected, CO level reduced from 0.77% to 0.46% at 6kg load.

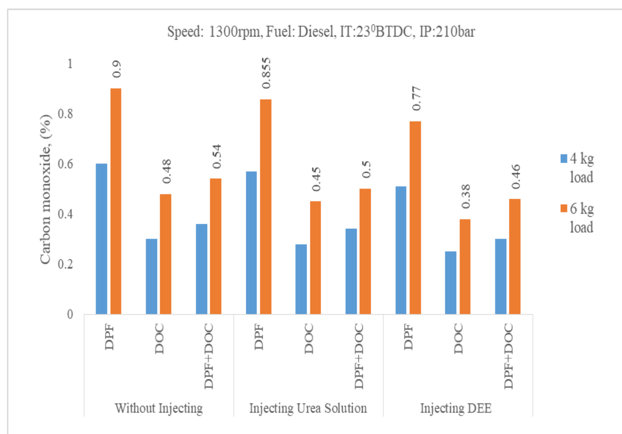

Fig. 13: Overall Comparison of CO emission

The overall comparison of NO_x without and with injecting of urea solution, and DEE is as shown in Fig. 14. There is a reduction in NO_x level from 576ppm to 540ppm during the test run of without urea solution injection and 462ppm to 446ppm when urea solution is injected[1,3]. However, when DEE is injected, NO_x level reduced from 530ppm to 495ppm at 6kg loads.

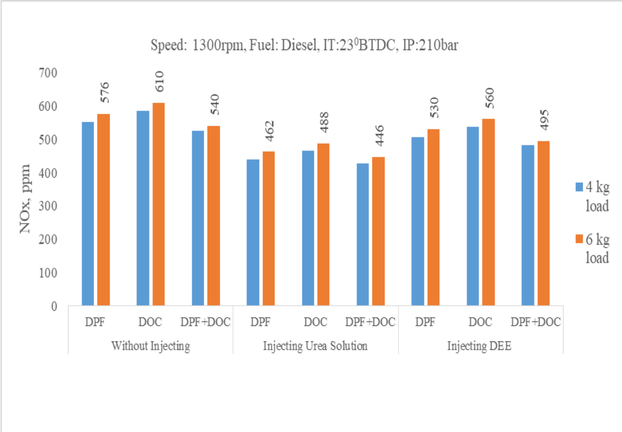

Fig. 14. Overall comparison of NO_x emission

IV. CONCLUSIONS

The effects of injecting urea and DEE solution in the exhaust pipe fitted with DPF and DOC on engine emissions were investigated. . All the emission values are compared with the diesel engine without DPF/DOC/fluid injection, the following conclusions are drawn

1) At 6kg loads the brake thermal efficiency without devices is found to be 21.45% and remains same with devices and fluid injection in exhaust pipe of diesel engine
2) CO emission reduced by 36% combining DPF, DOC and injecting urea solution.
3) NO_x emission reduced by 15% when DPF and DOC are combined and reduced by 30% when urea solution is injected in exhaust pipe. Hence, utilizing only DPF is not advisable and combination of both DPF, DOC and urea injection is suggested for better engine operation.
4) HC emission reduced by 9% when DEE is injected in exhaust pipe with DPF and DOC.
5) NO_x emission reduced by 15% when DPF and DOC are combined and when DEE is injected in exhaust pipe the NO_x emission was reduced by 22%
6) When the load is increased, fuel consumption is more as it leads to high combustion and emissions, which has been realized based on measured emission values. Compared to 6 Kg load emission levels; the 4 Kg load emission levels were lower

Overall comparison of all the results, it can be concluded that the least emission level was observed when engine is operated at 4kg load and having combined DPF, DOC and injecting urea solution. At this condition, the emissions values are CO 0.5%, HC 53 ppm, NO_x 446 ppm. Hence, there is need for combined DPF, DOC and urea solution injection at the exhaust pipe for an existing diesel engine.

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